UNITED STATES DEPARTMENT OF AGRICULTURE
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Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER December 20, 1915

WILLOWS:

THEIR GROWTH, USE, AND IMPORTANCE

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By

GEORGE N. LAMB, Forest Examiner

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By GEORGE N. LAMB, *Forest Examiner.*

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INTRODUCTION.

There are in the United States and Canada from 80 to 100 species of willows, distributed from the Gulf of Mexico to the Arctic Circle, and from tidewater to the tops of the highest mountains. They range from a tiny plant a few inches high to forest trees 4 feet in diameter and 140 feet in height. All the shrubbery species are useful as soil cover, forage, or basket material. Scarcely more than a dozen, however, are of prime economic importance. Of these, six are species imported from Europe: The basket willows, which are the American green willow (*Salix amygdalina*), the Lemley willow (*Salix pentandra*), and the purple willow (*Salix purpurea*), and three tree willows, the white willow (*Salix alba*), the crack willow (*Salix fragilis*), and the weeping willow (*Salix babylonica*). There is only one native tree species of wide distribution and importance, and this, the black willow (*Salix nigra*), is found from coast to coast and from the Lakes to the Gulf. It reaches tree size over most of this range, attaining its maximum development in the lower Mississippi bottom lands. The other native species of economic importance are *Salix amygdaloides*, *Salix cordata*, and *Salix fluviatalis*, which are primarily eastern and central species, and *Salix lasiandra*, *Salix laevigata*, *Salix lasiolepis*, and *Salix fendleriana*, the western tree willows.

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THE TREE AND ITS FORMS.

The botanical name of the willow genus, Salix, comes from the Celtic *sal*, meaning near, and *lis*, water. The poplar is a genus of the same family. Both have more species and wider distribution in North America than on any other continent, the willows being more widely distributed than the poplars but less generally attaining tree size.

The fruit of this group is the characteristic by which it is most easily distinguished. In both genera it is a catkin an inch or more long, made up of capsules borne on a stalk and containing a cottony mass to which are attached numerous minute seeds. The catkins of the willow are smaller than those of the poplar and are generally erect; those of the poplar are generally pendant. In both cases the seed has a tuft of silky hairs attached to the base. When the capsules open the tiny seeds are borne up by the cottony hairs and carried long distances by the wind. Willow seed consists of the bare embryo or new plant and is protected by a very thin covering. It germinates in a few hours in a moist place; but if it fails to secure this condition, it loses the power of germination in two or three days.

The willows can be distinguished from the poplars by their leaves, the poplars having typically long-stalked wide leaves; the willows, short-stalked narrow ones. Willow leaves occur alternately on the branches. There are several scales on each winter bud of the poplar, but only one on each willow bud.

The willows do not normally develop a strong taproot. However, those grown on dry upland situations and some of the drought-resistant species form semitaproot systems. Usually willows grow in moist situations and places where the water table is near the surface; so the root system is shallow, spreading, and fibrous.

The bark of the different species of tree willows is very much the same, and does not furnish an obvious means of distinguishing them, except in the case of the sandbar willow, which has almost smooth bark even in trees of considerable size.

The characteristics on which botanists separate the species are largely differences in the tiny flowers and the almost microscopical variations in the leaf parts. Several species are easily identified by the size, shape, or color of the leaves, but the majority have very similar gross characteristics.

BLACK WILLOW.

(*Salix nigra* Marsh.)

The black willow is by far the most important of the native species. In the region of its best development trees have been found 4 feet in diameter at breastheight and 140 feet in height. The leaves are

long and narrow, gradually running out into a long, usually curved tip. They are thin, occasionally sickle shaped, bright green, and rather shiny. In width they vary from one-eighth to three-fourths of an inch; in length from 3 to 6 inches, being usually about 3 inches. The buds are pointed, and one-eighth of an inch long. The flowers which are borne on aments terminal on leafy branches are from 1 to 3 inches long, with short yellow scales. The bark has characteristic corky protuberances on branches from 1 to 3 years old. These are particularly abundant on vigorous sprouts grown in the open and more occasionally in dense seedling stands. The bark of old trees is from 1 inch to 1½ inches thick, occasionally 2 inches.

The black willow group is spread from Maine to central Florida and westward to central Dakota, Nebraska, and Kansas, and through Texas, New Mexico, and Arizona up to northern California. Discriminating botanists break up the group into several species.

PEACHLEAF WILLOW.

(*Salix amygdaloides* Marsh.)

The peachleaf willow ranks next to the black willow in economic importance. It reaches a height of 60 t0 70 feet and a maximum diameter of 2 feet. The species is most easily distinguished from the black willow by its larger and broader leaves, generally whitish beneath. The bark is also distinctly smoother and the ridges firmer than that of the black willow. The leaves are from 3½ to 5 inches long and 1 inch wide. The buds are a dark chestnut brown, and one-eighth of an inch long. In general appearance the flowers are very similar to those of the black willow. The peachleaf willow is closely related to the black willow, and the two species hybridize freely, producing intermediate forms.

The range of the peachleaf willow is from northern New York, southwest (north of the Ohio River) through southwestern Arkansas and northern Texas, and northeast to central Washington, extending into Canada all across the continent. West of the Missouri it gradually replaces the black willow.

SANDBAR WILLOW.

(*Salix fluviatilis* Nutt.)

The sandbar, or narrow leaf, willow in its various forms is typically a shrub, found in practically the entire United States. It is particularly common on low river banks and on sand bars and new islands. A tendency to spread rapidly by root suckers makes it valuable as a soil binder. In the South Central States it has been reported as attaining a diameter of 2 feet and a height of 75 feet. This size is exceptional, and in the lower Mississippi Valley the

species is seldom over 40 feet in height and 6 inches in diameter. The narrow linear notched leaves make it easily distinguishable. They are one-eighth to one-third of an inch wide and 2 to 6 inches long. When young they are silky white, but generally become smooth at maturity. The buds and flowers resemble those of the peachleaf willow. The bark is grayish brown, and even in the large trees is scarcely furrowed. Old bark is somewhat rough.

In the mountains and on the dry plains several forms have developed which have been given separate names by botanists. From Quebec and Mackenzie to Virginia, Kentucky, Texas, and California several distinct forms have been recognized and given specific names. These variations occur principally in the western half of the United States.

DIAMOND WILLOW.

(*Salix cordata* Muhl.)

The diamond willow group has a wide distribution, and over a considerable portion of its range it occurs with great frequency. Like the sandbar willow, it has numerous forms, many of which have been given a variety of names or have been classed as separate species. Economically they can be treated as one group. The Missouri River type occasionally attains a height of 50 feet and a diameter of 18 inches, but as a rule none of the forms reaches a large size. Diamond willow is valuable chiefly for protecting stream banks and for post material. In portions of the dry prairie region diamond willow posts have been far more durable than any other native species. It is distinguished by the diamond-shaped leaf scars on the branches. The bark is also smooth and firm, somewhat similar to the sandbar willow but with more pronounced ridges. The leaves resemble the peachleaf willow at the base, but are wider in outline and more abruptly pointed. The hairy, reddish-brown winter buds, one-half inch long, also distinguish this species.

The range of the diamond willow is from New Brunswick to British Columbia, Virginia, Missouri, Colorado, and California.

WHITE WILLOW.

(*Salix alba* L.)

Of the willows imported from Europe the white willow is probably the most widely distributed in the United States. The earliest settlers brought cuttings to this country, and the species has now spread from coast to coast. It has been widely planted on the prairies and can now be found growing wild in most of the farming regions of the United States. As an individual tree it may attain a diameter of 5 to 8 feet, and when grown in stands, a height of 70 to 80 feet.

There are several forms of the white willow, one of which, the yellow willow (*Salix alba vitellina*), is as common as the white willow. The bright yellow bark of this variety and its greater inclination to branchiness readily distinguish it.

The white willow has pale-green leaves with silky pubescence on both sides, but at maturity the upper surface is nearly smooth. The edges are finely toothed. The mature leaves are from 2 to 4½ inches long and from one-third to two-fifths of an inch wide. The bark is from half an inch to 1½ inches thick on large trees, dark brown on the trunk with a reddish tinge higher up. It is deeply divided into broad, flat connecting ridges. Green, yellow, and red twigged forms are known to the trade.

CRACK WILLOW.

(*Salix fragilis* L.)

The crack willow, or gray willow, as it is often called, is quite similar in general appearance to the white willow. Under the same conditions it easily reaches the size attained by the white willow, but is in general a more slender and better formed tree. It is easily distinguished from the white willow by its larger, coarsely notched leaves and by its reddish-green twigs, which are extremely brittle at the base. The leaves are from half an inch to 1 inch wide, narrowed at the base, and from 3 to 6 inches long. At maturity they are smooth on both sides, dark green above and paler beneath. The bark is smooth and green on the upper portions of the tree. On the lower trunk it is rough, scaly, ridged, gray-brown, and 1 inch to 1½ inches thick. The crack willow does not produce so many water sprouts along the trunk as the white willow and therefore makes cleaner timber. It is undoubtedly the best willow species for plantations in the Prairie States. Many of the so-called white willow plantations are really crack willow. It is commonly planted in eastern, central, and northern United States. A yellow form is occasionally found in the nursery trade.

WEEPING WILLOW.

(*Salix babylonica* L.)

The weeping willow is another of the introduced species that is now widely scattered over the United States. Though a rapid grower at first, it does not reach the size attained by the white and crack willows. The height is seldom over 50 feet, but may occasionally reach 60 feet. The diameter is often from 3 to 5 feet when the tree is grown in the open. The weeping willow can readily be distinguished from the white willow, which it most closely resembles, by

its long drooping branchlets. These are tough and pliable, but the older branches are extremely brittle.

The leaves are long, narrow, and rounded at the base, light green above and pale beneath. They closely resemble those of the black willow in shape and those of the white willow in color. When young they are somewhat silky, but are smooth when mature. They are from 4 to 7 inches long and from one-fourth to one-half inch wide. In one variety, *Salix babylonica annularis*, the leaves curl into a ring. The bark on the trunk is from three-fourths of an inch to 1¼ inches thick, dark brown, becoming green or yellowish above. Besides the ring-leafed variety, a horticultural form with yellow twigs and a hairy northern variety are frequently seen.

The weeping willow is now widely planted as an ornamental tree and has frequently escaped from cultivation over practically the entire country.

PACIFIC COAST WILLOWS.

Besides the black and peachleaf willows there are five other species in the Pacific Coast States that attain tree size. None of these, however, are large enough for sawlogs and they are important chiefly for protection against erosion, although considerable quantities are available for charcoal or excelsior. This region, however, has such timber resources that it will be a long time before willow becomes as important as it is in the East. Along the coast in Oregon willows have been successfully planted as sand binders.

Four of the western willows are important. The *Salix lasiandra* (yellow willow) grows on the banks of streams throughout the coast ranges, Sacramento to San Joaquin Valleys, and Sierra Nevada southward to southern California and northward to British Columbia. It is from 20 to 80 feet high with stout reddish twigs and brown, roughly fissured bark. The 1-year-old branches are yellowish. The leaves are from 4 to 7 inches long and from five-eighths of an inch to 1¼ inches wide with a long tapering point. The *Salix laevigata* (red willow) is found along streams throughout California. It is a small tree from 20 to 40 feet high with reddish 1-year-old branchlets. The bark is firmer and lighter in color than the yellow willow. The leaves are also somewhat wider in outline. They are from 2½ to 7½ inches wide, green above and pale beneath. The *Salix lasiolepis* (arroyo willow) is commonly found along streams from Washington to California. It is a small tree from 15 to 40 feet high, easily distinguished by the almost smooth bark on the trunk. The branches are erect and have a yellowish bark. The leaves are shiny green above and whitish below, from 1½ to 5 inches long and from one-third of an inch to 1¼ inches wide. The *Salix fendleriana* (Fendler's willow) grows along mountain streams from eastern Washington

and California to New Mexico. It is a tree from 30 to 60 feet in height with dark brown rough bark. The twigs are long but not slender, reddish, or reddish-yellow in color. The leaves are dark green on both sides but somewhat paler beneath, from 3 to 8 inches long and from three-fifths of an inch to 1½ inches wide.

SOIL, MOISTURE, AND LIGHT.

Willows grow best in deep, rich, moist, alluvial bottom lands. The tree willows will grow on very poor soils, but usually as stunted trees or only large shrubs. In very sandy soils where rainfall is plentiful they grow thriftily but rather slowly. In dry soils or in soils subject to drought during a portion of the season the willows survive but grow slowly and become stag-headed at an early age. On heavy clay soils they grow moderately well if there is sufficient moisture, otherwise they survive with difficulty and seldom become trees. In good soils the willows endure a wide range of moisture conditions. Their adaptability, or rather their ability to survive, and their methods of reproduction have been responsible for their being crowded into wet places. Because they are seen so often in such places, the willows are often considered moisture-loving or swamp trees. The truth of the matter is that willows live in such places in spite of the excessive moisture conditions rather than because of them. Willows do, however, endure a period of inundation with less serious results than any but the southern swamp trees, such as cypress and water oak. They attain their best development along the lower Mississippi River, where these conditions and long growing seasons are found.

All willows are intolerant of shade. For this reason mature stands of willow are usually very open and a second-story forest exists. The black willow is slightly more tolerant than the sandbar willow and somewhat less than the peachleaf willow. Black willow is also slightly less tolerant than the cottonwood, although both are ranked as intolerant species.

SUSCEPTIBILITY TO INJURY.

INSECTS.

Willows are subject to the attack of a large number of insects, but only in exceptional seasons is the damage of a serious nature. Injury by insects is of three kinds: Defoliation, twig or shoot cutting, and bark or wood boring. The most important of these insects are fully discussed and illustrated as to appearance, habits, character of work, and remedies by Dr. F. H. Chittenden, in Bureau of Forestry Bulletin, No. 46, on pages 63–80, which may be purchased from the Superintendent of Documents, Government Printing Office. It is

recommended, therefore, that specimens of the insects, fresh evidence of their work, and a description of the character and extent of their injury be sent to the Forest Entomologist of the Bureau of Entomology for information and advice with regard to control measures.

FUNGI.

The injury caused by the various fungi, principally defoliation and decay in the wood, is probably less than that occasioned by insects. Willows with a sufficient ornamental value to warrant the expense can be kept free from leaf diseases by spraying. Where this is done, a relatively large amount of lime, rosin, or fish-oil soap is necessary to make the spray adhere to the leaves, especially those of the smooth-leaved species, such as the laurelleaf willow. The fungi that attack the wood are of the common type, known as bracket or shelf fungi, which gain admission to the tree through injuries caused by wind, insects, and the like. Some of these grow in the living tissue and destroy sound wood, but often they simply disintegrate portions that have been deadened by other agencies. The heartwood of the willow is particularly susceptible to such attacks. The dark-red heartwood of most of the willows does not show the ravages of decay until it has far advanced, often not until the fruiting bodies appear on the surface. In the black willow stands of the South the principal fungous troubles are large "burls," commonly known as "sap knots," and heart rot. The heart rot does not necessarily occur at the base of the tree and may extend for only a short distance, the wood being sound in either direction.

WIND AND GRAZING.

Probably the greatest enemy of the willow plantation is wind. The wide use of willows in exposed situations and the weakness of the green wood has been known to result in the almost complete demolition of individual trees and even rows of trees within 25 years after their establishment. In Iowa two rows were observed on apparently the same soil and extending in the same direction, one row exposed to the full sweep of the wind and the other protected by a cottonwood grove. Both rows were planted the same year and in the same manner. The protected row averaged 60 feet in height and only 3 per cent of the tops had been broken by the wind. In the other row 28 per cent of the trees averaged 55 feet high, and of these practically none of the tops were broken; so this height represented the normal. The other 72 per cent, however, were on an average only 40 feet high. All of these trees were more or less broken and cracked and could be saved from being completely wasted only by prompt utilization. At the age of 27 years the ex-

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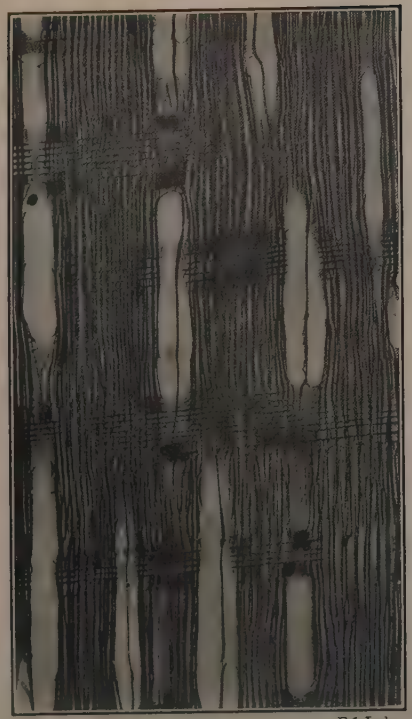
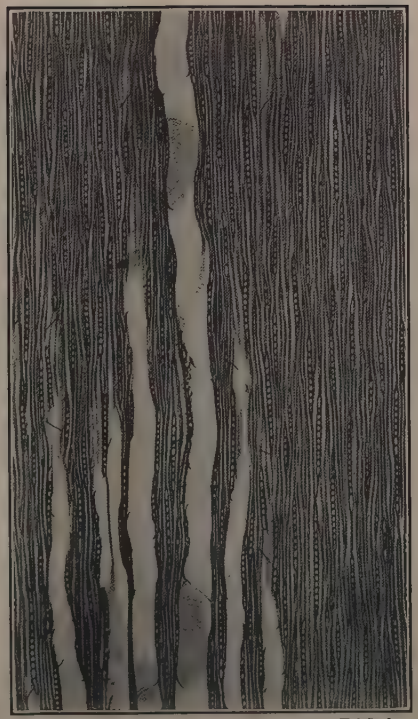
A LARGE RAFT OF BLACK WILLOW LOGS GROUNDED ON THE BANK OF THE YAZOO RIVER NEAR VICKSBURG, MISS.

Logs 24 feet long and from 18 inches to 36 inches in diameter at the small end.



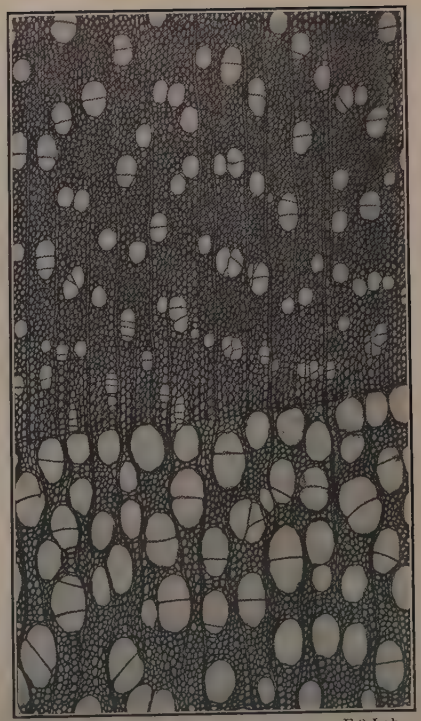
F-1-Lab.

FIG. 1.—RADIAL SECTION × 50.



F-2-Lab.

FIG. 2.—TANGENTIAL SECTION × 50.



F-3-Lab.

FIG. 3.—TRANSVERSE SECTION × 50.

BLACK WILLOW (SALIX NIGRA MARSH.).

posed grove was practically destroyed, while the other gave promise of unimpaired vigor for another 10 or 20 years.

In young willow plantations cattle, horses, sheep, and hogs eat the green shoots with avidity, and much damage may be done during the first 10 years of the life of the plantation. After that a small amount of browsing is often beneficial, as it clears the main stems of watershoots and small branches. Further injury by stock after this consists in barking the tree trunks, which hastens decay. The effect of grazing on the soil in the plantation is very harmful, and low yields and early decline mark the plantation where this practice is common.

FLOODS.

Willows on the flood plains of streams are more or less subject to injury during periods of high water. This has been noted as especially bad in willow plantations where the crop is pollarded, leaving a trunk from 8 to 10 feet in height. The injury to the trunk from floating débris and ice has resulted in the shortening of life, so that one or even two or three crops grown on a 7-year rotation have been lost. Such injury can be prevented by cropping at the ground and allowing the young vigorous shoots that are removed every few years to receive the blows rather than the stump, on the health of which depends the life of the pollard.

LIFE HISTORY OF THE BLACK WILLOW.

COMMERCIAL RANGE.

Of the native American species the black willow is by far the most important, on account of its wide range and its rapid growth under a variety of soil and moisture conditions. Over the greater part of its range this species is a tree willow and generally of considerable size. As a timber tree the black willow reaches its best development in the rich alluvial bottom lands of the lower Mississippi River and the lower portions of its tributaries. The quantity of merchantable black willow is much smaller than that of the cottonwood that formerly grew in this region, but to-day the cottonwood is rapidly disappearing and there is little doubt that there will soon be as much standing black willow as cottonwood between Cairo, Ill., and Baton Rouge, La. On the whole, however, it will average much lower in quality.

Most of the willow stands are found below the 35-foot stage of the river. They often occur above this mark, but are generally old trees and on being cut are replaced by cypress, gum, locust, ash, or other hardwoods. The same holds true for cottonwood to a large extent; the reproduction of old stands is very uncertain and the under story species generally takes the ground.

On the lower ground, such as small islands, old river beds, sand bars, and fills, the principal species present are black, sandbar, and peachleaf willows, and cottonwood above Cairo, Ill., the peachleaf dropping out below that point. Above Cairo the peachleaf willow divides with the black willow the position of the leading tree willow, but does not quite attain the size of the black willow or grow so rapidly. The black willow is prevalent along practically the whole course of the Mississippi, increasing in abundance and size along the lower reaches. The black willow and cottonwood are as a rule the first tree species to appear on new land.

FORM AND GROWTH OF INDIVIDUAL TREES.

Black willow trees may be divided into two general classes—that found in the North or on poor soil in the South and that of the rich alluvial river bottoms of the South. The first are typically 30 to 60 feet high and from 6 to 18 inches in diameter. They occur in pure stands over small areas or, more often, in groups of several clustered stems. In the open the black willow is a short, branchy, crooked tree, fit only for fuel. In close stands it has a moderately straight trunk or often two or three straight branches arising near the ground. The northern form, grown in close stands, can be utilized for fuel, charcoal, excelsior, or pulp, and occasionally for artificial limbs, but seldom develops into a desirable sawlog. The southern type is considerably different in habit of growth in the forest. The trunks are usually separate and stand quite erect. In the open the tree branches, like the northern form, being different only in its larger size. The forest-grown tree has a minimum clear length of 20 feet and an average clear length of about 40 feet, and, as a maximum, several specimens have been measured having over 80 feet of clear, straight bole. The tops of these trees are small, irregular, and often broken. The crowns are narrow, open, and deep. The average diameter in mature stands is about 18 inches at the mouth of the Ohio and increases to 24 inches in Mississippi and Louisiana. The largest breast-high diameter measurement recorded for a forest-grown black willow is 44 inches and the greatest height 140 feet. The tree with the greatest height measurement, however, was not the one with the greatest diameter growth. The 44-inch tree was not over 125 feet high and the 140-foot tree was not over 3 feet in diameter. The average height in mature stands at the mouth of the Ohio is approximately 85 feet; in Louisiana it ranges from 100 to 120 feet. Black willow is a short-lived tree. The greatest age recorded for a sound tree is 70 years; the greatest age recorded for a living but unsound tree is 85 years. The average age at which stands mature is 55 years and under favorable conditions may be 10 years less.

The bark of the forest-grown black willow varies considerably. On trees 2 feet or more in diameter it is usually 1.2 to 1.5 inches thick at stump height, as measured by the caliper or diameter tape. Typically it is rather soft and easily broken and sometimes hangs in loose flat scales. Occasionally it is very hard, the ridges being, therefore, deep.

The black willow has no pronounced taproot, although there may be several smaller roots extending downward beneath the trunk of the tree. On well-drained soils it develops a lateral root system, and on poorly drained soils where the water table is habitually near the surface of the ground the root system is decidedly lateral, uprooted trees often showing a depth of root of less than a foot.

TYPES AND ASSOCIATED SPECIES.

Practically all black willow stands have originated along the low banks of streams or lakes or have gained a foothold on areas which have received a generous deposit of sediment. The pure stands are usually on the lowest land or first bottoms. On the higher ground the willows are found to be mixed more and more with other species; in the North, principally elm, maple, ash, cottonwood, and boxelder, and in the South, cottonwood, with small amounts of ash, maple, sycamore, or cypress. The southern black willow stands must be considered temporary. Most of the land on which they are found is accretion land. Along the Mississippi the willow lands extend ordinarily from the water level to 35 feet above it, although the drainage conditions are more important in deciding this than the actual height of the land. In the extreme South, where there is a much larger area of bottom land than in the North, poor drainage results in the appearance of such species as cypress, water oak, and red gum in places where, with better drainage, cottonwood and willow would have been the first stand. The willow stand, whether it be along the rivers or in prairie plantations, must always be considered an advance guard or pioneer stand. As soon as soil or economic conditions improve it is generally replaced by other species.

GROWTH OF BLACK WILLOW.

HEIGHT GROWTH.

Black willow grows very rapidly in height, not only because of its inherent vigor but also as a result of the intense competition for light which is caused by its intolerance and the density of the stands in which it naturally comes up. Both the annual growth and the total height attained by the mature tree are greater in the South than in the North. Table 1 shows the average height of stands of approximately the same age at different points in the Mississippi Valley.

TABLE 1.—*Average height of willow stands in the Mississippi Valley.*

Stand near—	Age.	Stand.	Soil.	Average height.
	Years.			*Feet.*
Clay City, Ind.	53	Close	Sandy	82
Ste. Genevieve, Mo.	40	Medium	do	74
Cairo, Ill.	42	Close	do	83
Memphis, Tenn.	37	Medium	Very poor drainage	81
Helena, Ark.	55	Close	Black	110
Vicksburg, Miss.	41	do	do	98
St. Joseph, La.	45	do	do	116
Williamsport, La.	57	do	do	104

In the South black willow attains its principal height growth at from 35 to 40 years; in the North at from 30 to 35 years. In the South, however, growth frequently continues more slowly after this age until the heights ranging between 100 and 135 feet are reached. Table 2 gives the average height growth of black willow, based on 255 trees in the Mississippi Valley region from southern Indiana and southern Missouri to central Louisiana. Most of these measurements were taken in the southern half of this range.

TABLE 2.—*Height growth of black willow in the Mississippi Valley.*

(Based on 255 trees.)

Age.	Height.	Growth in 5-year periods.	Periodic annual growth.	Age.	Height.	Growth in 5-year periods.	Periodic annual growth.
Years.	*Feet.*	*Feet.*	*Feet.*	*Years.*	*Feet.*	*Feet.*	*Feet.*
5	32	32	6.4	35	96	7	1.4
10	50	18	3.6	40	101	5	1.0
15	63	13	2.6	45	105	4	.8
20	73	10	2.0	50	109	4	.8
25	82	9	1.8	55	113	4	.8
30	89	7	1.4	60	116	3	.6

DIAMETER GROWTH.

Black willow makes its most rapid diameter growth during the first 10 years, after which the growth falls off gradually. At the age of 60 years the average tree is generally mature or overmature, and produces little increment after that. Occasionally an individual will survive longer than this in a protected place and continue growing up to an age of 75 years. On poor sites, such as a rather sandy river bank, or on soils having a scant moisture supply, the diameter growth is about 0.4 of an inch per year for the first 10 years, while on the best sites in the South, where there is a long growing season, it averages from 0.5 to 0.7 of an inch. The maximum annual diameter growth on the best sites is 0.9 of an inch the first 10 years. A particularly interesting fact is noted in that beyond the age of 45 years the annual diameter growth of all trees is practically the same, averaging about 0.28 of an inch. The trees having a maximum

diameter growth gain their lead over the average trees during the first two decades. By thinning, the diameter growth can be made more sustained.

Table 3 is based on measurements of 34 trees in Arkansas with stumps 2.5 to 3.2 feet in diameter and 42 to 63 years old. Soil, a rich, moist bottom land. The trees when plotted were divided into three classes based on diameter growth. The minimum growth given in the table is the average for the slowest growing trees; the average growth is for the trees growing at a medium rate and the maximum growth is an average for the fastest growing trees. Neither the minimum nor the maximum growth is the slowest or fastest found for individual trees.

TABLE 3.—*Diameter growth of black willow, Phillips County, Ark.*

Age.	Diameter, breasthigh.			Increase in diameter by 5-year periods.		
	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.
Years.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
5	1.4	2.6	3.9	1.4	2.6	3.9
10	3.3	5.6	7.9	1.9	3.0	4.0
15	5.3	8.5	11.4	2.0	2.9	3.5
20	7.5	11.1	14.4	2.2	2.6	3.0
25	9.5	13.5	17.3	2.0	2.4	2.9
30	11.5	15.6	19.8	2.0	2.1	2.5
35	13.3	17.5	22.1	1.8	1.9	2.3
40	15.1	19.4	24.3	1.8	1.9	2.2
45	16.6	21.2	26.3	1.5	1.8	2.0
50	18.1	22.8	28.2	1.5	1.6	1.9
55	19.6	24.3	29.9	1.5	1.5	1.7
60	21.0	25.7	31.6	1.4	1.4	1.7

Table 4 is based on measurements of 76 trees in Mississippi with stumps 16 to 34.6 inches in diameter inside bark and 36 to 58 years old. Soil, a rich, moist bottom land.

TABLE 4.—*Diameter growth of black willow, Jefferson County, Miss.*

Age.	Diameter, breasthigh.			Increase in diameter by 5-year periods.		
	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.
Years.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
5	1.9	3.1	4.9	1.9	3.1	4.9
10	3.9	6.5	9.0	2.0	3.4	4.1
15	5.9	9.5	12.6	2.0	3.0	3.6
20	7.5	12.2	15.9	1.8	2.7	3.3
25	9.0	14.4	18.7	1.5	2.2	2.8
30	10.4	16.2	21.4	1.4	1.8	2.7
35	11.7	17.9	23.8	1.3	1.7	2.4
40	13.0	19.3	26.0	1.3	1.4	2.2
45	14.2	20.8	27.8	1.2	1.5	1.8
50	15.4	22.2	29.3	1.2	1.4	1.5
55	16.7	23.5	30.7	1.3	1.3	1.4
60	17.7	24.7	31.8	1.0	1.2	1.1

VOLUME IN BOARD MEASURE.

The following tables are based on taper tables constructed from measurements of 256 selected trees, taken principally in Arkansas, Mississippi, and Louisiana, with a few in Missouri and Indiana. All measurements were taken on trees less than 60 years old, growing on rich alluvial bottom lands. Practically all the trees measured were felled in logging operations. The figures in heavy-faced type indicate the volumes of trees of average heights. Table 5 shows the volume based on diameters breasthigh from 14 to 36 inches, and heights 10 feet apart from 60 to 130 feet. The top diameter limit runs from 10 inches in the 14-inch trees to 26 inches in the 36-inch trees, giving very incomplete utilization. Table 6 shows the volume based on diameters breasthigh and number of 16-foot logs per tree.[1] The trees forming the basis of both tables were scaled with the Scribner Decimal C rule.

TABLE 5.—*Black willow—Mississippi Valley.*

Diameter breasthigh.	Total height of tree—feet.								Diameter inside bark of top.	Basis.
	60	70	80	90	100	110	120	130		
	Volume—board feet.									
Inches.									*Inches.*	*Trees.*
14	60	90	120	**150**	160	.....	.....	.....	10	.....
15	70	100	140	**170**	190	.....	.....	.....	11	2
16	80	120	160	190	**210**	.....	.....	.....	12	3
17	90	140	180	210	**240**	.....	.....	.....	12	11
18	100	160	200	240	**270**	280	.....	.....	13	9
19	.....	180	220	270	**300**	320	.....	.....	14	6
20	.....	200	250	300	**330**	360	370	.....	14	12
21	.....	220	280	340	**370**	400	410	.....	15	23
22	.....	250	320	370	410	**440**	460	480	16	25
23	.....	270	350	410	450	**490**	510	540	17	23
24	.....	300	390	450	490	**530**	560	590	17	23
25	.....	.....	430	490	540	**580**	620	650	18	15
26	.....	.....	470	530	590	**630**	670	700	19	15
27	.....	.....	520	580	630	**680**	730	760	19	16
28	.....	.....	570	630	680	**730**	780	820	20	9
29	.....	.....	620	680	740	**790**	840	880	21	7
30	.....	.....	670	730	790	**840**	900	940	22	8
31	.....	.....	.....	780	840	**900**	950	1,000	22	8
32	.....	.....	.....	830	890	**950**	1,010	1,070	23	3
33	.....	.....	.....	880	950	**1,000**	1,070	1,130	24	6
34	.....	.....	.....	930	1,000	**1,060**	1,130	1,190	24	3
35	.....	.....	.....	990	1,050	**1,120**	1,190	1,260	25	1
36	.....	.....	.....	1,040	1,100	**1,170**	1,250	1,320	26	1
										229

[1] Scaled from taper curves mostly in 16.3-foot logs with a few shorter logs where necessary. Stump height, 1 foot.

TABLE 6.—*Black willow—Mississippi Valley.*

Diameter breast-high.	Number of 16-foot logs.					Diameter inside bark of top.	Basis.
	1	1½	2	2½	3		
	Volume—board feet.						
Inches.						*Inches.*	*Trees.*
14	62	97	130	170	.....	10	.....
15	72	120	160	200	.....	11	2
16	83	140	180	230	.....	12	3
17	96	160	210	260	.....	12	11
18	110	180	250	300	.....	13	9
19	130	210	280	350	.....	14	6
20	140	240	320	390	.....	14	12
21	160	260	350	440	.....	15	23
22	180	290	390	490	.....	16	25
23	210	320	430	540	.....	17	23
24	230	350	470	600	730	17	23
25	250	380	520	660	810	18	15
26	280	410	560	730	890	19	15
27	.....	440	610	800	980	19	16
28	.....	480	670	870	1,070	20	9
29	.....	510	720	940	1,160	21	7
30	.....	550	780	1,020	1,260	22	8
31	.....	590	840	1,100	1,360	22	8
32	.....	630	900	1,180	1,460	23	3
33	.....	670	960	1,260	1,570	24	6
34	.....	700	1,020	1,340	1,670	24	3
35	.....	740	1,080	1,430	1,780	25	1
36	.....	780	1,140	1,510	1,880	26	1
							229

Tables 7 and 8 are similar to Tables 5 and 6 except that the trees were scaled with the Doyle instead of the Scribner Decimal C rule.

TABLE 7.—*Black willow—Mississippi Valley.*

Diameter breast-high.	Total height of tree—feet.								Diameter inside bark of top.	Basis.
	60	70	80	90	100	110	120	130		
	Volume—board feet.									
Inches.									*Inches.*	*Trees.*
14	52	64	82	100	130	140	.....	.....	10	.....
15	60	80	100	120	150	160	.....	.....	11	2
16	68	97	120	150	170	180	190	.....	12	3
17	73	110	150	170	190	210	220	.....	12	11
18	79	130	170	200	220	240	250	270	13	9
19	.....	150	200	230	250	270	290	310	14	6
20	.....	180	230	270	290	310	330	350	14	12
21	.....	200	260	300	330	360	370	390	15	23
22	.....	230	290	340	370	400	420	440	16	25
23	.....	260	330	380	410	450	470	490	17	23
24	.....	290	360	420	460	500	520	540	17	23
25	.....	.....	400	470	510	550	570	600	18	15
26	.....	.....	450	510	560	600	620	660	19	15
27	.....	.....	490	560	610	650	680	710	19	16
28	.....	.....	540	610	660	710	740	770	20	9
29	.....	.....	590	660	720	760	800	840	21	7
30	.....	.....	650	710	770	820	860	900	22	8
31	.....	.....	.....	760	820	880	920	970	22	8
32	.....	.....	.....	810	870	940	990	1,040	23	3
33	.....	.....	.....	860	920	1,000	1,050	1,100	24	6
34	.....	.....	.....	920	980	1,060	1,120	1,170	24	3
35	.....	.....	.....	970	1,030	1,120	1,190	1,240	25	1
36	.....	.....	.....	1,020	1,090	1,180	1,250	1,310	26	1
										[illegible]

TABLE 8.—*Black willow—Mississippi Valley.*

Diameter breast-high.	Number of 16-foot logs.					Diameter inside bark of top.	Basis.
	1	1½	2	2½	3		
	Volume—board feet.						
Inches.						*Inches.*	*Trees.*
14	40	69	100	130	.....	10	.....
15	51	89	120	160	.....	11	2
16	64	110	150	190	.....	12	3
17	78	130	180	230	.....	12	11
18	94	160	210	270	.....	13	9
19	110	180	240	310	.....	14	6
20	130	210	280	350	430	14	12
21	150	230	320	400	490	15	23
22	170	260	360	450	550	16	25
23	200	290	400	500	610	17	23
24	220	320	440	560	680	17	23
25	240	360	490	620	750	18	15
26	270	390	530	680	830	19	15
27	.....	420	580	740	910	19	16
28	.....	460	640	810	1,000	20	9
29	.....	500	690	890	1,090	21	7
30	.....	530	750	970	1,190	22	8
31	.....	570	810	1,050	1,290	22	8
32	.....	600	870	1,140	1,400	23	3
33	.....	640	940	1,240	1,520	24	6
34	.....	670	1,000	1,330	1,640	24	3
35	.....	710	1,070	1,430	1,770	25	1
36	.....	750	1,140	1,530	1,900	26	1

Tables 9 and 10 are similar to Tables 5 and 6, respectively, except in regard to closeness of utilization. Table 9 shows the volume based on diameters breasthigh from 8 to 36 inches and height classes 10 feet apart, from 60 to 130 feet, and also the average height of trees of different diameters. The top diameter limit is from 6 inches for the 8-inch trees up to 16 inches for the 36-inch trees. The volumes of trees of average heights are shown in heavy-faced type. Table 10 shows the volume based on diameters breasthigh from 8 to 36 inches and the number of 16-foot logs per tree, scaled from taper curves, mostly in 16.3-foot logs, with a few shorter lengths where necessary. The stump height is 1 foot. The trees on which both tables are based were scaled with the Scribner Decimal C rule and the tables show what could be taken from them by close utilization.

TABLE 9.—*Black willow—Mississippi Valley.*

Diameter breast-high.	Total height of tree—feet.								Average height.	Diameter inside bark of top.	Basis.
	60	70	80	90	100	110	120	130			
	Volume—board feet.										
Inches.									*Feet.*	*Inches.*	*Trees.*
8	19	30	43	57	.....	.....	.....	.....	58	6	11
9	26	42	55	71	.....	.....	.....	.....	65	6	5
10	36	56	70	90	.....	.....	.....	.....	71	6	5
11	47	70	89	110	.....	.....	.....	.....	76	6	2
12	59	86	110	140	170	.....	.....	.....	81	6	.....
13	72	100	140	170	200	.....	.....	.....	86	6	.....
14	89	130	160	200	230	250	.....	.....	90	6	.....
15	110	150	190	230	270	290	.....	.....	93	6	2
16	120	170	220	270	300	330	350	.....	96	6	3
17	140	200	250	300	340	380	400	.....	98	6	11
18	160	230	290	340	390	430	460	490	100	6	9
19	.....	260	320	380	440	480	520	560	101	6	6
20	.....	290	360	430	490	540	580	630	103	6	12
21	.....	320	400	480	550	600	650	700	104	7	23
22	.....	360	450	540	610	670	720	780	105	7	25
23	.....	400	500	600	670	740	800	860	106	8	23
24	.....	440	550	660	740	810	880	940	107	8	23
25	.....	.....	620	730	810	890	960	1,020	108	9	15
26	.....	.....	690	800	890	970	1,050	1,110	109	10	15
27	.....	.....	770	880	970	1,060	1,140	1,200	109	10	16
28	.....	.....	860	960	1,060	1,150	1,230	1,300	110	11	9
29	.....	.....	.....	1,040	1,140	1,240	1,330	1,400	110	11	7
30	.....	.....	.....	1,130	1,230	1,330	1,430	1,510	111	12	8
31	.....	.....	.....	1,210	1,320	1,430	1,530	1,630	111	13	8
32	.....	.....	.....	1,290	1,420	1,530	1,640	1,740	112	13	3
33	.....	.....	.....	1,380	1,510	1,630	1,750	1,860	112	14	6
34	.....	.....	.....	1,460	1,600	1,740	1,860	1,980	113	14	3
35	.....	.....	.....	1,550	1,700	1,840	1,970	2,100	113	15	1
36	.....	.....	.....	1,630	1,790	1,950	2,090	2,220	113	16	1
											352

TABLE 10.—*Black willow—Mississippi Valley.*

Diameter breast-high.	Number of 16-foot logs.										Diameter inside bark of top.	Basis.
	2	2½	3	3½	4	4½	5	5½	6	6½	7	
	Volume—board feet.											
Inches.												*Trees.*
8	38	52	64	.....	.....	.....	.....	.....	.....	.....	.....	6	11
9	41	56	70	.....	.....	.....	.....	.....	.....	.....	.....	6	5
10	46	61	78	90	.....	.....	.....	.....	.....	.....	.....	6	5
11	51	68	87	100	.....	.....	.....	.....	.....	.....	.....	6	2
12	58	76	99	120	150	170	200	.....	.....	.....	.....	6	.....
13	66	87	110	130	160	190	220	.....	.....	.....	.....	6	.....
14	76	98	130	150	180	210	240	270	300	.....	.....	6	.....
15	85	110	140	170	210	240	270	300	330	.....	.....	6	2
16	97	130	160	190	230	270	300	340	370	400	.....	6	3
17	.....	140	180	220	260	300	340	380	410	450	.....	6	11
18	.....	160	200	240	290	330	380	420	460	500	540	6	9
19	.....	.....	220	270	320	370	420	470	520	560	610	6	6
20	.....	.....	240	300	360	420	470	530	580	630	680	6	12
21	.....	.....	270	340	410	470	530	590	650	700	750	7	23
22	.....	.....	300	380	460	530	600	670	730	790	840	7	25
23	.....	.....	340	430	510	600	670	750	820	880	940	8	23
24	.....	.....	380	480	570	670	750	830	910	980	1,040	8	23
25	.....	.....	.....	540	640	740	830	920	1,000	1,070	1,150	9	15
26	.....	.....	.....	610	710	830	920	1,010	1,100	1,180	1,270	10	15
27	.....	.....	.....	690	790	910	1,010	1,110	1,200	1,290	1,390	10	16
28	.....	.....	.....	780	870	1,000	1,110	1,210	1,310	1,410	1,510	11	9
29	.....	.....	.....	.....	960	1,090	1,210	1,320	1,430	1,530	1,640	11	7
30	.....	.....	.....	.....	1,040	1,180	1,310	1,440	1,560	1,680	1,790	12	8
31	.....	.....	.....	.....	1,120	1,280	1,420	1,560	1,690	1,830	1,940	13	8
32	.....	.....	.....	.....	1,210	1,370	1,530	1,690	1,840	2,000	2,110	13	3
33	.....	.....	.....	.....	1,300	1,470	1,640	1,820	1,990	2,170	2,300	14	6
34	.....	.....	.....	.....	1,390	1,560	1,760	1,950	2,130	2,330	2,490	14	3
35	.....	.....	.....	.....	1,480	1,660	1,870	2,090	2,280	2,500	2,690	15	1
36	.....	.....	.....	.....	1,570	1,760	1,990	2,220	2,430	2,670	2,890	16	1
													252

VOLUME IN CUBIC FEET.

Table 11 gives in cubic feet the total volume, including bark, of trees from 5 to 44 inches in diameter, and from 40 to 140 feet high. The table is based on measurements of 256 trees, taken mostly in Arkansas, Mississippi, and Louisiana, with a few in Missouri and Indiana. The volumes of trees of average height are shown in heavy-faced type.

TABLE 11.—*Black willow—Mississippi Valley.*

Diameter breast-high.	Total height of tree—feet.											Basis.
	40	50	60	70	80	90	100	110	120	130	140	
	Total volume of stem, including bark—cubic feet.											
Inches.												*Trees.*
5	2.8	3.5	4.3	5.0	.....	.....	.....	.....	.....	.....	.....	.....
6	4.1	5.1	6.1	7.1	.....	.....	.....	.....	.....	.....	.....	1
7	5.6	6.9	8.3	9.7	10.9	.....	.....	.....	.....	.....	.....	7
8	7.3	9.1	10.9	12.7	14.2	.....	.....	.....	.....	.....	.....	7
9	9.2	11.5	13.8	16.1	18.0	20	.....	.....	.....	.....	.....	6
10	11.3	14.2	17.0	19.9	22	25	.....	.....	.....	.....	.....	5
11	13.7	17.2	21	24	27	30	32	.....	.....	.....	.....	2
12	16.3	20	25	29	32	35	38	.....	.....	.....	.....	.....
13	.....	24	29	34	38	41	45	49	.....	.....	.....	.....
14	.....	28	33	39	44	48	52	56	.....	.....	.....	.....
15	.....	32	38	45	50	55	60	65	69	.....	.....	2
16	.....	36	44	51	57	63	68	74	79	.....	.....	3
17	.....	.....	49	57	64	71	77	83	89	92	.....	11
18	.....	.....	55	64	72	80	87	93	100	103	.....	9
19	.....	.....	61	72	80	89	96	104	111	115	119	6
20	.....	.....	68	79	89	98	107	115	123	128	131	12
21	.....	.....	.....	88	98	108	118	127	136	141	145	22
22	.....	.....	.....	96	108	119	129	139	149	154	159	23
23	.....	.....	.....	105	118	130	141	152	163	169	174	23
24	.....	.....	.....	114	128	141	154	166	177	184	189	24
25	.....	.....	.....	.....	139	153	167	180	192	199	205	15
26	.....	.....	.....	.....	150	166	181	195	208	216	222	14
27	.....	.....	.....	.....	162	179	195	210	224	233	239	15
28	.....	.....	.....	.....	174	192	210	226	241	250	257	9
29	.....	.....	.....	.....	.....	206	225	242	259	268	276	9
30	.....	.....	.....	.....	.....	221	241	259	277	287	296	8
31	.....	.....	.....	.....	.....	236	257	277	296	307	316	8
32	.....	.....	.....	.....	.....	251	274	295	315	327	336	3
33	.....	.....	.....	.....	.....	267	291	314	335	348	358	6
34	.....	.....	.....	.....	.....	284	309	333	356	369	380	3
35	.....	.....	.....	.....	.....	.....	327	353	377	391	402	1
36	.....	.....	.....	.....	.....	.....	346	373	399	414	426	1
37	.....	.....	.....	.....	.....	.....	366	394	421	437	449	.....
38	.....	.....	.....	.....	.....	.....	386	416	444	461	474	.....
39	.....	.....	.....	.....	.....	.....	406	438	468	485	499	.....
40	.....	.....	.....	.....	.....	.....	428	461	492	511	525	.....
41	.....	.....	.....	.....	.....	.....	.....	484	517	536	552	.....
42	.....	.....	.....	.....	.....	.....	.....	508	543	563	579	.....
43	.....	.....	.....	.....	.....	.....	.....	532	569	590	607	.....
44	.....	.....	.....	.....	.....	.....	.....	558	596	618	636	1
												256

SOLID CONTENT OF CORDS.

The solid content in cubic feet of stacked cords made up of trees of different diameters can be ascertained by referring to the following table. The solid content of trees from 1 to 5 inches in diameter such as furnish the brush used in revetment work, for which the whole tree is taken, was computed from the average weight of a cord of brush as compared with the weight of a cord of excelsior wood. The remainder of the table was computed from measurements taken in Indiana where excelsior wood was being cut in the woods from trees 3 to 12 inches in diameter, from measurements taken in Louisiana, and from wood being bolted for staves.

TABLE 12.—*Solid content in cubic feet of stacked cords from trees of different sizes.*

Diameter of trees.	Solid content of a cord.
Inches.	*Cubic feet.*
[1] Brush...	53
3 to 10...	75
10 to 15...	88
15 to 20...	91
20 to 25...	93
25 to 30...	94

[1] Used in revetment work along Mississippi River; includes trees from 1 to 5 inches in diameter.

IMPORTANCE OF CLOSE UTILIZATION.

Table 13 gives, for average trees, loss in board feet and percentage of loss through imperfect utilization. Column 2 shows the average height of trees of different diameters. Column 3 is the cubic-foot content for trees of this size as given in Table 11. Column 4 is the board-foot content of the same trees as given in Table 5, showing wasteful utilization. Column 5 is the board-foot content of the same trees taken from Table 9, showing close untilization. Column 6 is the difference between wasteful and close utilization in board feet, and column 7 gives the percentage of loss in board feet resulting from imperfect utilization. The difference runs from 25 per cent in the 14-inch trees to 40 per cent in the 36-inch trees.

TABLE 13.—*The loss in board feet of the willow timber left in the woods.*

Diameter.	Height.	Cubic content.	Volume.			Per cent of loss.
			Close utilization.	Wasteful utilization.	Loss.	
Inches.	*Feet.*	*Cubic feet.*	*Board feet.*	*Board feet.*	*Board feet.*	
8	58	10.9	19	.....	19	.....
9	65	16.1	42	.....	42	.....
10	71	19.9	56	.....	56	.....
11	76	27	89	.....	89	.....
12	81	32	110	.....	110	.....
13	86	41	170	.....	170	.....
14	90	48	200	150	50	25.0
15	93	55	230	170	60	26.1
16	96	68	300	210	90	30.0
17	98	77	340	240	100	29.4
18	100	87	390	270	120	30.8
19	101	96	440	300	140	31.8
20	103	107	490	330	160	32.7
21	104	118	550	370	180	32.7
22	105	139	670	440	230	34.3
23	106	152	740	490	250	33.8
24	107	166	810	530	280	34.6
25	108	180	890	580	310	34.8
26	109	195	970	630	340	35.1
27	109	210	1,060	680	380	35.8
28	110	226	1,150	730	420	36.5
29	110	242	1,240	790	450	36.3
30	111	259	1,330	840	490	36.8
31	111	277	1,430	900	530	37.1
32	112	295	1,530	950	580	37.9
33	112	314	1,630	1,000	630	38.7
34	113	333	1,740	1,060	680	39.1
35	113	353	1,840	1,120	720	39.1
36	113	373	1,950	1,170	780	40.0

FORM TABLES.

The foregoing volume tables were made by scaling the average tree in each diameter and height class, and are intended to show the volume of the trees according to the log scales most commonly used both under the present system of utilization and under a closer system. In each case, however, the diameter limit established is an arbitrary matter and the volume shown applies only for the particular log scale used. In the following form tables the actual average taper measurements are given, and from these it is possible to construct volume tables for any log scale and any degree of utilization. Moreover, tables can be constructed to show the contents of the trees not only in board feet but in any other unit, such as cordwood, posts, etc., that may be desired. In the form tables are shown diameter classes from 8 inches to 36 inches at intervals of 1 inch and height classes from 60 to 130 feet at intervals of 10 feet. The heights above ground represent 16.3-foot logs and half logs plus a stump height of 1 foot. The tables are based on the measurement of 252 trees in Indiana, Arkansas, Missouri, Louisiana, and Mississippi.

TABLE 14.—*Diameters inside bark at different heights above the ground for trees of different sizes, based on measurements of 252 trees in Indiana, Arkansas, Missouri, Mississippi, and Louisiana.*

(The heights above ground represent 16.3-foot logs and half logs, plus a stump height of 1 foot.)

Diameter breasthigh.	60-FOOT TREES.						70-FOOT TREES.							
	Height above ground—feet.													
	4.5	9.15	17.3	25.45	33.6	41.75	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05
Inches.	Diameter inside bark—inches.													
8	7.4	6.8	6.0	5.1	4.0	2.8	7.4	6.9	6.2	5.5	4.8	3.8	2.8	1.8
9	8.3	7.7	6.7	5.7	4.6	3.2	8.3	7.8	7.0	6.3	5.5	4.4	3.3	2.1
10	9.2	8.6	7.4	6.2	4.9	3.5	9.2	8.7	7.8	7.0	6.0	4.9	3.8	2.4
11	10.1	9.5	8.3	6.9	5.5	3.9	10.1	9.5	8.6	7.7	6.6	5.4	4.2	2.7
12	11.0	10.4	9.0	7.5	5.9	4.2	11.0	10.4	9.4	8.4	7.2	6.0	4.6	3.0
13	11.9	11.3	9.8	8.2	6.5	4.6	11.9	11.3	10.2	9.2	7.9	6.5	5.0	3.4
14	12.9	12.1	10.5	8.8	6.8	4.9	12.9	12.1	11.0	9.8	8.5	7.0	5.5	3.7
15	13.8	13.0	11.4	9.4	7.4	5.4	13.8	13.0	11.8	10.6	9.2	7.6	5.9	4.0
16	14.8	13.9	12.0	10.0	7.9	5.7	14.8	13.9	12.6	11.2	9.8	8.1	6.3	4.3
17	15.7	14.7	12.8	10.5	8.3	6.1	15.7	14.8	13.3	11.9	10.4	8.7	6.7	4.6
18	16.7	15.6	13.5	11.2	8.8	6.5	16.7	15.7	14.1	12.6	11.0	9.2	7.2	4.8
19	.....	.....	.....	.....	.....	.....	17.6	16.5	14.8	13.3	11.7	9.8	7.6	5.1
20	.....	.....	.....	.....	.....	.....	18.6	17.3	15.5	13.9	12.3	10.4	8.1	5.4
21	.....	.....	.....	.....	.....	.....	19.5	18.2	16.3	14.6	13.0	10.9	8.5	5.6
22	.....	.....	.....	.....	.....	.....	20.5	19.2	17.1	15.3	13.6	11.5	8.9	5.8
23	.....	.....	.....	.....	.....	.....	21.5	20.0	17.8	16.0	14.2	12.0	9.4	6.2
24	.....	.....	.....	.....	.....	.....	22.5	20.9	18.6	16.7	14.9	12.6	9.9	6.4

TABLE 14.—*Diameters inside bark at different heights above the ground for trees of different sizes, etc.*—Continued.

80-FOOT TREES.

Diameter breasthigh.	Height above ground—feet.								
	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2
Inches.	Diameter inside bark—inches.								
8	7.4	7.1	6.6	6.1	5.5	4.9	4.1	3.2	2.2
9	8.3	7.9	7.3	6.8	6.2	5.5	4.6	3.6	2.5
10	9.2	8.7	8.1	7.6	7.0	6.1	5.1	4.0	3.0
11	10.1	9.6	8.9	8.3	7.6	6.7	5.6	4.5	3.3
12	11.0	10.4	9.7	9.0	8.3	7.2	6.1	4.9	3.6
13	11.9	11.3	10.5	9.8	8.9	8.0	6.7	5.4	4.0
14	12.9	12.2	11.3	10.5	9.6	8.6	7.3	5.8	4.3
15	13.8	13.0	12.1	11.3	10.3	9.2	7.8	6.3	4.7
16	14.8	14.0	13.0	12.0	11.0	9.8	8.4	6.8	5.0
17	15.7	14.9	13.8	12.7	11.7	10.5	8.9	7.2	5.4
18	16.7	15.8	14.6	13.5	12.3	11.1	9.5	7.7	5.8
19	17.6	16.7	15.4	14.3	13.0	11.7	10.0	8.2	6.2
20	18.6	17.5	16.3	15.0	13.7	12.3	10.6	8.7	6.5
21	19.5	18.5	17.0	15.7	14.4	12.9	11.2	9.2	6.8
22	20.5	19.4	17.9	16.5	15.1	13.6	11.8	9.7	7.2
23	21.5	20.4	18.7	17.3	15.9	14.3	12.4	10.2	7.6
24	22.5	21.2	19.5	18.0	16.5	14.9	13.0	10.7	7.8
25	23.5	22.2	20.3	18.8	17.2	15.6	13.6	11.3	8.2
26	24.5	23.1	21.2	19.5	17.9	16.3	14.2	11.7	8.5
27	25.5	24.1	22.0	20.3	18.7	17.0	14.8	12.3	8.9
28	26.5	25.2	23.0	21.2	19.5	17.7	15.5	12.9	9.4
29	27.5	26.0	23.6	21.8	20.2	18.4	16.0	13.3	9.7
30	28.5	26.9	24.5	22.6	20.9	19.0	16.6	13.9	10.1

90-FOOT TREES.

Diameter breasthigh.	Height above ground—feet.										
	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5
Inches.	Diameter inside bark—inches.										
8	7.4	7.1	6.8	6.5	6.2	5.8	5.2	4.6	4.0	3.2	1.9
9	8.3	8.0	7.6	7.3	7.0	6.5	5.8	5.2	4.5	3.5	2.0
10	9.2	8.8	8.4	8.1	7.7	7.0	6.4	5.7	4.9	3.8	2.2
11	10.1	9.7	9.2	8.9	8.4	7.7	6.9	6.1	5.2	4.2	2.4
12	11.0	10.6	10.0	9.6	9.0	8.3	7.5	6.6	5.6	4.5	2.6
13	11.9	11.5	10.9	10.3	9.7	9.0	8.0	7.0	6.0	4.8	2.7
14	12.9	12.4	11.7	11.1	10.5	9.5	8.6	7.6	6.5	5.1	3.0
15	13.8	13.2	12.4	11.8	11.1	10.2	9.1	8.0	6.9	5.4	3.1
16	14.8	14.1	13.2	12.6	11.8	10.8	9.7	8.6	7.3	5.8	3.4
17	15.7	15.0	14.0	13.3	12.5	11.5	10.4	9.1	7.7	6.1	3.5
18	16.7	15.9	14.9	14.0	13.2	12.2	11.0	9.6	8.1	6.4	3.8
19	17.6	16.8	15.6	14.7	13.8	12.8	11.5	10.1	8.5	6.7	3.9
20	18.6	17.7	16.5	15.5	14.6	13.4	12.1	10.6	9.0	7.0	4.0
21	19.5	18.6	17.3	16.3	15.2	14.1	12.7	11.2	9.4	7.3	4.3
22	20.5	19.5	18.1	17.0	16.0	14.7	13.3	11.7	9.9	7.7	4.5
23	21.5	20.4	18.9	17.8	16.7	15.4	13.9	12.3	10.3	8.0	4.6
24	22.5	21.4	19.7	18.5	17.4	16.0	14.5	12.9	10.8	8.3	4.9
25	23.5	22.2	20.5	19.3	18.0	16.7	15.1	13.4	11.3	8.7	5.1
26	24.5	23.2	21.4	20.0	18.8	17.3	15.7	14.0	11.7	9.0	5.2
27	25.5	24.1	22.1	20.7	19.4	18.0	16.3	14.6	12.3	9.4	5.4
28	26.5	25.1	23.0	21.4	20.0	18.6	17.0	15.2	12.8	9.8	5.6
29	27.5	26.0	23.8	22.1	20.8	19.3	17.5	15.7	13.3	10.1	5.7
30	28.5	26.9	24.6	22.8	21.4	19.9	18.2	16.3	13.8	10.6	6.0
31	29.5	27.9	25.3	23.5	22.1	20.6	18.7	16.8	14.3	11.0	6.1
32	30.5	28.9	26.3	24.2	22.8	21.3	19.4	17.4	14.9	11.4	6.2
33	31.5	29.7	27.0	24.9	23.4	21.9	20.0	18.0	15.5	11.8	6.4
34	32.5	30.7	27.8	25.6	24.1	22.6	20.7	18.6	16.0	12.4	6.5
35	33.5	31.6	28.4	26.3	24.8	23.2	21.3	19.2	16.6	12.8	6.7
36	34.5	32.6	29.3	27.0	25.4	23.8	21.9	19.7	17.1	13.2	6.8

TABLE 14.—*Diameters inside bark at different heights above the ground for trees of different sizes, etc.*—Continued.

100-FOOT TREES.

Diameter breasthigh.	Height above ground—feet.											
	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65
Inches.	Diameter inside bark—inches.											
12	11.0	10.5	10.1	9.8	9.3	8.7	8.0	7.4	6.7	5.8	4.3	2.4
13	11.9	11.4	10.9	10.5	10.0	9.4	8.6	8.0	7.2	6.2	4.7	2.6
14	12.9	12.3	11.7	11.3	10.7	10.0	9.3	8.5	7.7	6.6	5.0	2.8
15	13.8	13.2	12.6	12.0	11.4	10.7	9.9	9.1	8.1	7.0	5.4	2.9
16	14.8	14.0	13.4	12.8	12.1	11.4	10.5	9.6	8.6	7.4	5.7	3.1
17	15.7	14.9	14.2	13.6	12.7	12.0	11.2	10.2	9.1	7.8	6.0	3.2
18	16.7	15.8	15.0	14.3	13.5	12.7	11.8	10.8	9.6	8.2	6.3	3.5
19	17.6	16.7	15.9	15.1	14.1	13.3	12.4	11.3	10.1	8.7	6.7	3.7
20	18.6	17.7	16.6	15.7	14.9	14.0	13.0	11.9	10.6	9.1	7.0	3.9
21	19.5	18.6	17.6	16.6	15.6	14.6	13.6	12.5	11.1	9.5	7.4	4.1
22	20.5	19.5	18.3	17.3	16.2	15.3	14.3	13.1	11.6	10.0	7.7	4.3
23	21.5	20.4	19.1	18.0	16.9	16.0	14.9	13.6	12.1	10.4	8.1	4.5
24	22.5	21.3	20.0	18.7	17.6	16.7	15.5	14.2	12.6	10.9	8.4	4.7
25	23.5	22.3	20.8	19.5	18.3	17.3	16.0	14.7	13.2	11.3	8.7	4.8
26	24.5	23.3	21.6	20.2	19.0	17.9	16.6	15.3	13.7	11.7	9.0	5.0
27	25.5	24.2	22.4	20.9	19.7	18.5	17.2	15.8	14.2	12.2	9.3	5.2
28	26.5	25.2	23.2	21.6	20.4	19.1	17.8	16.4	14.7	12.6	9.6	5.4
29	27.5	26.1	24.0	22.3	21.0	19.8	18.4	16.9	15.2	13.1	10.0	5.6
30	28.5	27.1	24.8	23.0	21.7	20.5	19.0	17.5	15.7	13.5	10.3	5.8
31	29.5	28.0	25.5	23.7	22.3	21.1	19.6	18.1	16.3	13.9	10.6	6.0
32	30.5	28.9	26.3	24.4	23.0	21.7	20.2	18.6	16.8	14.4	10.9	6.3
33	31.5	29.7	27.0	25.0	23.6	22.3	20.8	19.1	17.3	14.8	11.3	6.5
34	32.5	30.7	27.8	25.7	24.3	23.0	21.4	19.7	17.9	15.3	11.6	6.7
35	33.5	31.5	28.5	26.4	25.0	23.6	22.0	20.3	18.4	15.8	11.9	6.9
36	34.5	32.5	29.4	27.2	25.7	24.2	22.6	20.8	19.0	16.3	12.3	7.1

110-FOOT TREES.

Diameter breasthigh.	Height above ground—feet.														
	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	106.95	115.1
Inches.	Diameter inside bark—inches.														
14	12.9	12.5	11.9	11.2	10.6	10.1	9.6	9.0	8.2	7.3	6.3	5.0	2.9	.....	.....
15	13.8	13.4	12.7	12.0	11.3	10.7	10.1	9.5	8.8	7.8	6.7	5.3	3.1	.....	.....
16	14.8	14.2	13.5	12.8	12.1	11.4	10.8	10.1	9.3	8.3	7.1	5.5	3.2	.....	.....
17	15.7	15.1	14.3	13.5	12.8	12.1	11.4	10.7	9.8	8.8	7.5	5.8	3.4	.....	.....
18	16.7	16.0	15.1	14.3	13.5	12.8	12.1	11.3	10.3	9.3	7.9	6.0	3.5	.....	.....
19	17.6	16.9	16.0	15.1	14.3	13.5	12.6	11.9	10.9	9.7	8.3	6.3	3.7	.....	.....
20	18.6	17.8	16.8	15.9	15.1	14.2	13.3	12.4	11.4	10.2	8.7	6.6	3.9	.....	.....
21	19.5	18.7	17.6	16.7	15.8	14.9	13.9	13.0	11.9	10.7	9.1	6.8	4.0	.....	.....
22	20.5	19.7	18.4	17.4	16.5	15.5	14.6	13.6	12.5	11.2	9.5	7.1	4.2	.....	.....
23	21.5	20.6	19.3	18.2	17.1	16.2	15.2	14.2	13.0	11.7	9.9	7.3	4.3	.....	.....
24	22.5	21.5	20.2	18.9	17.9	16.9	15.9	14.8	13.6	12.2	10.3	7.7	4.5	.....	.....
25	23.5	22.5	21.0	19.7	18.6	17.6	16.6	15.4	14.1	12.7	10.7	8.0	4.6	.....	.....
26	24.5	23.4	21.8	20.4	19.3	18.3	17.2	16.0	14.7	13.2	11.2	8.2	4.8	.....	.....
27	25.5	24.3	22.6	21.1	20.0	18.9	17.8	16.6	15.2	13.7	11.5	8.6	4.9	.....	.....
28	26.5	25.2	23.4	21.9	20.7	19.6	18.4	17.2	15.8	14.1	11.9	8.8	5.1	.....	.....
29	27.5	26.2	24.2	22.6	21.4	20.3	19.0	17.7	16.3	14.7	12.3	9.1	5.2	.....	.....
30	28.5	27.1	24.9	23.3	22.1	20.9	19.6	18.3	16.9	15.2	12.8	9.4	5.4	.....	.....
31	29.5	28.1	25.8	24.0	22.7	21.5	20.2	18.9	17.4	15.7	13.2	9.7	5.5	.....	.....
32	30.5	29.0	26.6	24.7	23.3	22.1	20.8	19.4	18.0	16.2	13.5	10.1	5.7	.....	.....
33	31.5	29.9	27.3	25.4	24.0	22.7	21.4	20.0	18.5	16.6	14.0	10.3	5.8	.....	.....
34	32.5	30.9	28.1	26.0	24.6	23.3	22.0	20.6	19.1	17.2	14.4	10.7	6.0	.....	.....
35	33.5	31.8	28.9	26.7	25.3	24.1	22.6	21.1	19.6	17.6	14.8	10.9	6.1	.....	.....
36	34.5	32.7	29.6	27.3	25.9	24.6	23.2	21.7	20.1	18.1	15.2	11.3	6.3	.....	.....

TABLE 14.—*Diameters inside bark at different heights above the ground for trees of different sizes, etc.*—Continued.

120-FOOT TREES.

Diameter breast-high.	Height above ground—feet.														
	4.5	9.15	17.3	25.45	33.6	41.75	49.9	58.05	66.2	74.35	82.5	90.65	98.8	106.95	115.1
Inches.	Diameter inside bark—inches.														
16	14.8	14.3	13.6	12.8	12.1	11.5	10.7	10.1	9.4	8.7	7.9	6.8	5.0	3.1	.....
17	15.7	15.2	14.4	13.6	12.9	12.2	11.4	10.8	10.0	9.2	8.3	7.1	5.3	3.3	.....
18	16.7	16.1	15.2	14.4	13.6	12.9	12.2	11.4	10.5	9.7	8.8	7.5	5.6	3.5	.....
19	17.6	17.0	16.1	15.2	14.3	13.5	12.7	12.0	11.2	10.2	9.3	7.9	5.9	3.7	.....
20	18.6	17.9	16.9	15.9	15.0	14.3	13.4	12.6	11.8	10.8	9.6	8.2	6.2	3.8	.....
21	19.5	18.8	17.7	16.7	15.8	15.0	14.1	13.3	12.3	11.3	10.1	8.6	6.5	4.0	.....
22	20.5	19.7	18.6	17.4	16.5	15.7	14.8	13.9	12.9	11.8	10.6	9.0	6.8	4.2	.....
23	21.5	20.7	19.4	18.2	17.2	16.4	15.5	14.5	13.5	12.4	11.0	9.3	7.1	4.4	.....
24	22.5	21.6	20.2	19.0	18.0	17.1	16.2	15.1	14.0	12.9	11.5	9.7	7.4	4.5	.....
25	23.5	22.5	21.0	19.7	18.7	17.8	16.8	15.8	14.7	13.5	12.0	10.1	7.6	4.7	.....
26	24.5	23.5	21.9	20.5	19.4	18.5	17.5	16.4	15.3	13.9	12.4	10.4	7.9	4.9	.....
27	25.5	24.4	22.7	21.2	20.1	19.2	18.2	17.1	15.9	14.5	12.8	10.8	8.1	5.1	.....
28	26.5	25.3	23.5	22.0	20.8	19.8	18.8	17.6	16.4	15.0	13.3	11.1	8.4	5.2	.....
29	27.5	26.2	24.3	22.7	20.5	21.5	19.4	18.2	17.0	15.6	13.7	11.5	8.6	5.4	.....
30	28.5	27.2	25.1	23.4	22.2	21.2	20.1	18.8	17.5	16.1	14.2	11.8	8.9	5.6	.....
31	29.5	28.1	25.9	24.1	22.8	21.8	20.7	19.4	18.0	16.5	14.6	12.1	9.1	5.8	.....
32	30.5	29.1	26.7	24.8	23.5	22.5	21.3	20.0	18.6	17.1	15.1	12.5	9.4	5.9	.....
33	31.5	30.0	27.5	25.5	24.2	23.0	21.9	20.6	19.1	17.6	15.5	12.8	9.6	6.1	.....
34	32.5	30.9	28.3	26.2	24.8	23.7	22.5	21.1	19.7	18.1	16.0	13.2	9.9	6.2	.....
35	33.5	31.9	29.0	27.0	25.5	24.3	23.1	21.7	20.2	18.6	16.4	13.5	10.1	6.5	.....
36	34.5	32.8	29.9	27.7	26.2	24.9	23.7	22.3	20.7	19.1	16.9	13.9	10.4	6.6	.....

130-FOOT TREES.

18	16.7	16.2	15.3	14.4	13.6	12.8	12.0	11.4	10.7	10.0	9.4	8.8	7.6	5.7	3.5
19	17.6	17.1	16.2	15.3	14.4	13.6	12.8	12.0	11.3	10.6	9.9	9.3	7.9	6.0	3.7
20	18.6	18.0	17.1	16.1	15.2	14.3	13.5	12.7	11.9	11.1	10.4	9.6	8.3	6.3	4.0
21	19.5	18.9	17.9	16.9	15.9	15.0	14.3	13.4	12.6	11.8	11.0	10.1	8.6	6.6	4.2
22	20.5	19.8	18.7	17.6	16.6	15.7	14.9	14.0	13.1	12.2	11.4	10.5	8.9	6.9	4.5
23	21.5	20.8	20.5	18.4	17.4	16.5	15.6	14.7	13.8	12.9	11.9	10.9	9.3	7.2	4.7
24	22.5	21.7	19.5	19.1	18.1	17.2	16.3	15.4	14.4	13.4	12.4	11.3	9.6	7.5	5.0
25	23.5	22.7	21.2	19.9	18.8	18.0	17.0	16.0	15.0	13.9	12.8	11.6	9.9	7.8	5.2
26	24.5	23.6	22.0	20.6	19.6	18.7	17.7	16.7	15.6	14.5	13.4	12.1	10.3	8.1	5.5
27	25.5	24.5	22.8	21.4	20.2	19.3	18.4	17.3	16.1	15.1	13.8	12.5	10.6	8.4	5.6
28	26.5	25.4	23.7	22.1	20.9	20.0	19.1	18.0	16.8	15.6	14.3	12.9	11.0	8.6	5.9
29	27.5	26.3	24.4	22.9	21.7	20.7	19.7	18.6	17.4	16.2	14.8	13.2	11.3	8.9	6.1
30	28.5	27.2	25.3	23.6	22.3	21.3	20.3	19.2	18.0	16.7	15.2	13.6	11.6	9.1	6.3
31	29.5	28.2	26.0	24.3	23.0	22.0	21.0	19.9	18.6	17.3	15.7	14.0	11.9	9.4	6.5
32	30.5	29.1	26.9	25.1	23.7	22.7	21.7	20.5	19.2	17.7	16.2	14.4	12.3	9.7	6.7
33	31.5	30.1	27.7	25.8	24.4	23.3	22.3	21.1	19.8	18.3	16.6	14.7	12.7	10.0	6.9
34	32.5	31.0	28.5	26.5	25.1	24.0	23.0	21.7	20.4	18.9	17.1	15.1	13.0	10.2	7.2
35	33.5	31.9	29.3	27.3	25.8	24.6	23.6	22.4	21.0	19.5	17.6	15.5	13.3	10.5	7.4
36	34.5	32.8	30.1	27.9	26.4	25.3	24.2	23.0	21.6	20.0	18.0	15.9	13.6	10.8	7.6

YIELD (SMALL SAMPLE AREAS).

The yield of the black willow varies greatly. Typically mature willow is usually found with cottonwood, occasionally in extensive pure stands. Even when grown with cottonwood it often occurs in pure groups or pockets of from 10 to 100 trees. Of the sample plots listed in the following table, Nos. 1, 2, and 3, near Helena, Ark., were selected from an area of several hundred acres on which willow occurred in varying amounts, averaging about 33 per cent of the total stand. In plots 4, 5, and 6, near Rodney, Miss., the willow was mixed with cottonwood and made up only about 8 per cent of the

total stand on approximately 1,000 acres. It occurred generally in groups one-eighth acre to 3 or 4 acres in extent. In plots 7, 8, and 9, on Raccourci Island, Williamsport, La., the willow stand was almost pure over several thousand acres. At other places the plots were in pure stands, ranging from 1 acre to 100 acres. In scaling the plots Table 9 was used. The top diameters shown in Table 5 more nearly represent the actual practice in cutting willow under the present wasteful lumbering, but in order to make a fairer comparison with cottonwood or other species more closely utilized it was considered desirable to base the yield on approximately the same utilization as for cottonwood.

TABLE 15.—*Yield of black willow in the Mississippi Valley south of Cairo, Ill.*

WELL-STOCKED STANDS.

Plot No.	Location.	Size of plot.	Age.	Trees per acre.	Average height.	Yield per acre		
	State.	*Acres.*	*Years.*		*Feet.*	*Cubic feet.*	*Board ft.*	*Cords.*
12	Missouri	0.25	35	76	84	6,608	28,320	66
11	Tennessee	.25	40	84	90	8,968	41,920	89
10	do	.50	45	98	90	10,418	46,820	104
5	Mississippi	.50	45	34	116	6,124	30,340	61
4	do	.25	47	56	116	7,888	41,280	79
6	do	.25	50	52	116	8,140	39,840	81
7	Louisiana	2.50	55	41	110	7,800	38,360	78
8	do	1.00	55	36	107	7,004	33,989	70
1	Arkansas	.25	55	64	110	1,008	49,760	90
2	do	.25	58	40	106	6,113	30,960	61
3	do	.25	58	56	109	9,016	48,560	90
9	Louisiana	2.50	58	56	103	6,809	42,280	87

UNDERSTOCKED STANDS.

21	Mississippi	0.25	27	52	104	5,488	25,360	55
13	Missouri	.25	37	58	75	4,992	20,800	50
14	do	.25	41	62	62	4,836	19,400	48
19	Mississippi	.25	47	32	105	4,300	20,720	43
20	do	.25	47	32	100	4,640	22,400	46
16	Arkansas	.25	49	36	97	4,556	21,440	46
15	do	.25	50	36	96	5,356	25,800	54
17	Tennessee	.25	51	56	86	5,482	24,400	55
18	do	.25	51	68	66	6,208	27,280	62
22	Louisiana	.25	55	28	94	3,844	26,404	38

MANAGEMENT OF WILLOW ON OVERFLOW BOTTOM LANDS.

The black willow is now receiving the attention of lumbermen because it is a substitute for cottonwood, which is being rapidly exhausted, and because it is especially adapted for management on the Mississippi bottom lands. The failing supply of cottonwood will be largely replaced by red gum for some purposes; but black willow must also become increasingly prominent, for it can be used in many ways and it is much lighter in weight than red gum, which, on account of the long distances this lumber must be shipped to reach the northern markets, is a decided advantage.

Cottonwood is a better tree for planting than willow, but for the management of natural growth black willow is in many respects superior. It seeds as abundantly as cottonwood, reproduces by cuttings, and survives, when young, a greater variety of unfavorable conditions. The land that is in no danger of being inundated, covered

with sediment, or cut away by the river, is too valuable agriculturally to be used for forest plantations. This leaves only overflow lands for forest purposes, and the condition of these is so unstable as to make the artificial establishment of plantations too precarious an investment to attract capital. The inferior timber on the ground and the natural reproduction will therefore continue to be utilized instead of better species being planted. Under these conditions the probability of success in forest management is greater with willow than with cottonwood.

The main problem in the management of bottom lands is how to encourage the best species. In this discussion the lands considered are those lying below the 35-foot stage of the river. Above this mark the willows are usually replaced by better species. The lower areas are covered by a mixture of black willow, cottonwood, and sandbar willow, the last being both the most prolific and the least desirable. In the management of such areas the only way at present of encouraging the best species is to cut intelligently the material used in revetment work. By limiting the cuttings to stands of sandbar willow and leaving the cottonwood and black willow, the prevalence of the sandbar willow can be much reduced. In mixed stands, 7 to 12 years old, where all three species occur, all the cottonwood and enough of the black willow to stock the ground completely should be left. If from 200 to 300 trees of cottonwood or black willow be left to the acre, the first crop of willows for revetment will suffer but a slight reduction and the second crop of sprout growth will receive but little shading from the trees left. The third crop of revetment willows will necessarily be smaller, but such a thinning can easily be made profitable; then after the period of these two crops, ranging from 10 to 15 years, the original trees left will soon make a complete canopy. By this method, at practically no expense more than directing the cutting of the brush, a worthless area covered with mixed growth may be converted into timberland of considerable value. In further thinnings the cottonwood, if present, should be favored except on land that is receiving large accretions. On such land the black willow generally survives the cottonwood.

CHARACTERISTICS OF WILLOW WOOD.

Willow is characteristically a light wood. It varies considerably in weight in different species and under different growing conditions. The wood of the slow-growing species and shrubby forms is usually heavier than that of the larger and more rapid-growing species. The diamond willow is heavier and harder than the other native willows of economic importance. There is little difference in the weight of the wood of black, white, and crack willows, the specific gravity ranging from 0.4 to 0.45.

The wood of the male trees of the white willow is heavier than that of the female trees of the same species [1] and on the same soil. This may be due to the usually faster growth of the pistillate trees that has been frequently observed. In planting to obtain wood for a particular purpose this characteristic should be taken into consideration.

Willow wood in the sap is whitish to creamy yellow and in the heart pink to reddish brown. Occasionally the heart of the black willow of the lower Mississippi is a light bluish gray when dry.

The annual rings of all willows are relatively indistinct, the wood being quite uniform throughout. The rings of white and crack willow are much less distinct than those of the black willow. The black willow can be readily distinguished from the other two species even without a hand lens, provided a smooth transverse surface is cut. No clear and constant distinction was found between the white and crack willows. The white willow shows a tendency toward being more porous in the early wood, the pores often being larger than those in the crack willow, so that the medullary rays bend around them, but their character is not constant and occasionally the crack willow shows the same structure.

TO DISTINGUISH WHITE AND BLACK WILLOW WOOD.

In the black willow wood (*Salix nigra*) the pores diminish considerably in size and number toward the outer portion of the growth ring, with a strong tendency toward being grouped in wavy tangential lines in the late wood. The heartwood is of a dirty reddish-brown or grayish-brown color. In the white willow wood (*Salix alba vitellina* and *Salix fragilis*) the pores diminish only slightly in size and number toward the outer portion of the growth ring and do not have the tendency toward being grouped in wavy tangential lines in the late wood. The heartwood is of a clear salmon-brown color.

USES OF WILLOW WOOD.

LUMBER.

According to census reports and millmen in the South, willow lumber has been cut in limited quantities for the last 8 or 10 years. It was marketed and used locally under the name of black or brown cottonwood until the last 7 years. Since then the production has increased until willow has found a place on the market under its true name. Practically all of the material so utilized has been cut from the black willow on the lower Mississippi, principally between Memphis, Tenn., and Baton Rouge, La., although small quantities

[1] E. R. Platt, "The variations of *Salix alba*," Quar. Jour. Forestry.

have been manufactured in the Middle Western States from planted groves of white and crack willow. The white and crack willow lumber is used locally in farm buildings and to a small extent in rough interior carpentry work. Much of the black willow is barged up the Mississippi to the vicinity of Cairo, Ill., where it is graded and distributed through the Northern States, principally in Iowa, Illinois, Michigan, and Wisconsin.

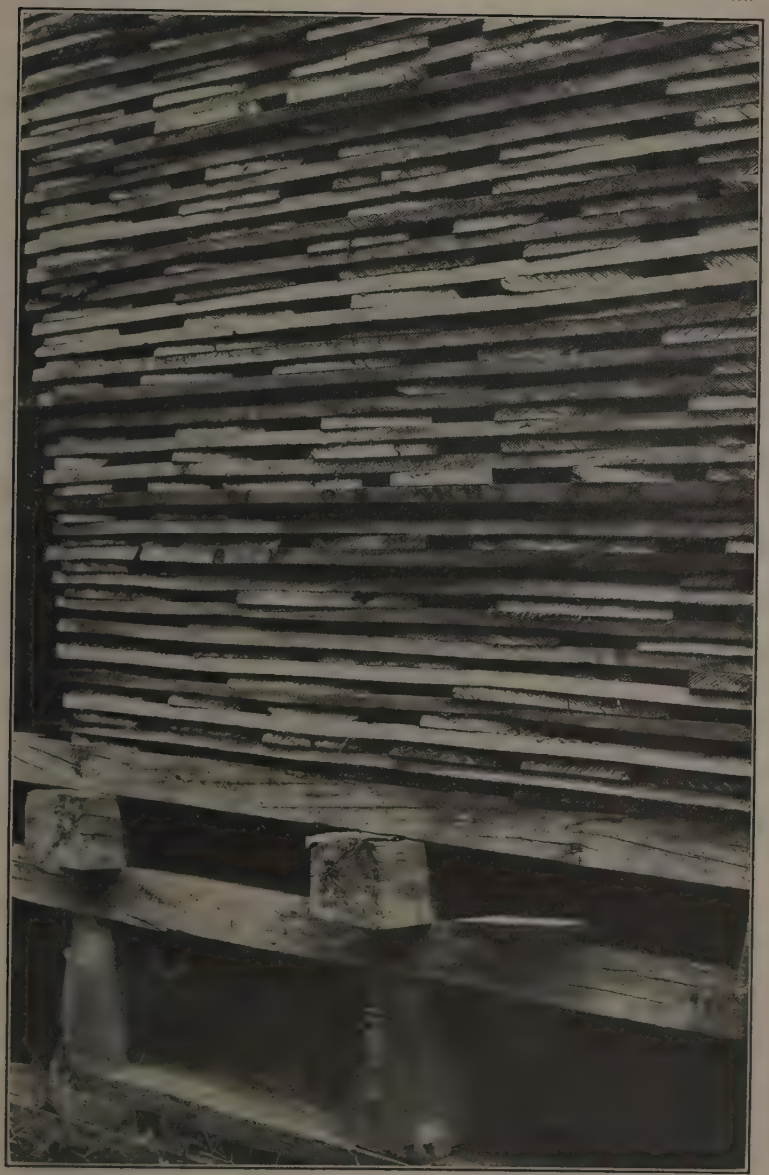
The average grade of willow lumber on the market is high, because only large clear logs are at present sawed into lumber. This entails great waste in the woods, as only a small part of the tree is taken. With a closer utilization the percentage of the poorer grades will increase considerably. The average willow now being cut is very little inferior to the average cottonwood. The following table shows the grades from average and select logs of willow, as compared with cottonwood, along the lower Mississippi:

	Cottonwood.[1]		Black willow.[2]		Black willow, mill run, lumber graded at Cairo, Ill.
	Select logs.	Average.	Select logs.	Average.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Boxboards	7	9	5		
Firsts and seconds	40	18	30	20	32
No. 1 common	35	30	25	30	40
No. 2 common	15	42	38	48	25
No. 3 common	5	1			3
Mill cull			2	2	

[1] Department of Agriculture Bulletin 24.
[2] Based on annual mill-cut figures at two 20,000 daily capacity mills.

The price of willow lumber has increased steadily since it was put on the market. It was first shipped North in 1909 or 1910 and sold at from $10 to $12 per thousand, mill run, f. o. b. at the mill. At this price there was no profit for the manufacturer, and the lumber was secured and cut more or less as an experiment. It was easily marketed, and a request was immediately made for more. Since that time the price has risen to $16 per thousand, mill run. In Chicago and Grand Rapids furniture manufacturers pay from $24 to $25 per thousand for clear lumber. Further rises will only follow the general market. At present the cost of handling willow lumber is as high as is usually the case with a new product. Most of the willow shipped North is handled several times, and this adds materially to the cost. With a low-grade lumber it is especially important that it be handled as directly as possible.

A number of sawmills and cooperage mills on the lower Mississippi, visited in the fall of 1913 in the course of this study, reported that they were using between 23,000,000 and 25,000,000 feet of black willow. Half of this went into box shooks or slack cooperage stock. Sawmills, in reporting their annual production of lumber,



F-15256A

PILED WILLOW LUMBER, NO. 1 COMMON, VICKSBURG, MISS., 1913.

F-15638A

Cutting Bolts for Excelsior from Young Stands of Black Willow Along the Wabash River in Southern Indiana, 1913.

often list willow as cottonwood, so that available statistics do not indicate the full production of willow lumber.

Willow lumber is light, 1-inch lumber weighing when thoroughly seasoned from 2,300 to 2,500 pounds per thousand board feet. This makes it as cheap to transport as yellow poplar. The wood varies in color considerably. When first cut it runs from dark reddish brown to blue and almost black, but when dry it is much lighter. Thoroughly seasoned wood is for the most part a light reddish brown with perhaps 10 per cent of it a grayish blue. Willow lumber, cut from only the best trees, as is the custom now, is seldom shaky, and when properly handled it checks scarcely at all. With close utilization the percentage of shaky lumber would increase considerably. Willow planking is satisfactory where strength is not of prime importance, since it does not warp, splinter, or check, and wears out very slowly. It makes good barn and cell floors. The grades of willow lumber are firsts and seconds, No. 1 and No. 2 common, and the grading rules are similar to those used for cottonwood.

Willow lumber of the high grades is used mostly in the North for furniture drawers and backing, while the poorer grades are used largely in the South for box material. As a substitute wood willow is very promising and for many uses equal to basswood. In fact, for many of the purposes for which willow was once used and for which it has scarcely a superior, basswood, poplar, and cottonwood were substituted because of their prevalence and relatively low cost. As willow comes back on the market at a lower price than these it bids fair to gain favor.

A part of the willow lumber now manufactured is being used for refrigerators, pianos, cabinetwork, and furniture. Here it has taken the place of basswood, elm, or sap gum. As yet it has only been used for interior work, but it should eventually find a place in the manufacture of cheap furniture; for although it does not take a high polish, it takes a very attractive dull finish and can be stained to present a very creditable imitation of some of the costlier cabinet woods.

Willow is suitable for small boats and athletic goods because it may be dented and bruised without splintering, and for keels, water wheels, paddles, and bungs because it is durable in water. It has always been used by leather workers for lapboards, cutting boards, and cutting tables, for which its lightness and spongy softness make it particularly desirable. Intense heat will not warp or split willow; therefore it is suitable for sleeve or ironing boards and for wheelbarrows for carrying ore, coal, or ashes in hot furnace rooms. Toys and novelties are now being made of it. For these, low-grade lumber can be worked up very closely and the dark color is scarcely a drawback because most of such articles are stained or painted.

SLACK COOPERAGE STOCK.

For a number of years willow has been manufactured into slack cooperage stock in New Orleans and other places on the lower Mississippi River. It was reported in the census returns of 1907 as furnishing 2,000,000 staves and 106,000 sets of headings. In 1908 these figures had more than doubled, being 4,485,000 and 240,000, respectively. In 1909 the production dropped over 25 per cent, but in 1910 it increased again, and manufacturers state that since then the reduction in the supply of other woods has led to even greater use of willow. Louisiana has from the beginning led in the utilization of willow in slack cooperage. Most of the mills are located in the vicinity of New Orleans and receive their logs from as far up the river as Vicksburg. The stave mills take logs above 16 feet in length and 8 inches in diameter. These logs are secured at a low cost and rafted down the river. From near-by points off the river the mills also bring in considerable material by rail, which is generally bolted in the woods into 21-inch pieces for heading and 32-inch pieces for staves. Willow cooperage is produced in two grades, No. 1 being used principally for sugar, rice, and asphalt, and No. 2 for potatoes, oysters, bottles, garden truck, and vegetables. The cull stock goes into half barrels.

EXCELSIOR.

Excelsior mills have been using willow for several years, those in Kentucky, Indiana, Missouri, Kansas, and Tennessee especially. The principal species used so far has been the black willow. It is taken in small sizes, most of the trees being under 12 inches in diameter and under 20 years in age. Trees of this size when grown close together furnish bolts relatively straight and free from defects. The wood is also largely sap and is thus much lighter in color than could be got from older and larger trees. The bolts are generally cut 4½ feet long in the woods and are then recut to 18 inches at the mill. The unit used in measuring this wood is a rank 4 by 4½ by 8 feet. Most of the willow for this purpose has been cut during the growing season, because at that time the peeling can be done at low cost. In Indiana the chopper cuts the bark at the base of the standing tree and then strips it upward in three or four strips as far as possible. After the trees are felled, the stripping is completed before the bolting is done. The cost of felling by this method was not over 25 cents per cord. The long hanging strips of bark are also extremely useful in dropping the trees, as in thick mixed stands the trees are apt to lodge. Willow cut in winter requires almost as much time for peeling as for felling and bolting, and, at the present price of $2 per rank for stacked, peeled, and split wood, a laborer would find it difficult to make fair wages.

Excelsior is usually manufactured into three grades—coarse, medium, and fine, the latter being called wood wool. Willow goes into the first two grades, but not into the wood wool, largely on account of its color. Pure willow excelsior is seldom seen, because the willow is usually worked in more or less as an adulterant. Candy manufacturers discriminate against willow excelsior on the ground that it taints their wares.

Excelsior manufacturers in Indiana pay $7 to $7.50 per rank delivered at the mill for peeled willow cut in 4½-foot lengths. The pieces must be not more than 6 inches in diameter or split so that at least one side of a quartered log is not wider than 6 inches.

CHARCOAL.

Though most of the charcoal manufactured is a side product of wood-distillation plants, the making of willow charcoal has been a separate industry for years. Willow charcoal is especially suitable for certain grades of black powder, and is in demand for chemical and medicinal purposes because it produces a very pure carbon. Several powder mills in the Eastern States, after having used all the native willows within many miles of the mill, have induced farmers to plant willows. These people, following the example of the powder mills, have grown "pollard" willows by setting out long poles and then cropping at intervals the sprouts produced at the top.

The general price paid for "powder willows" delivered at the mills has been $6 per cord, green, or $7.50 per cord, peeled. Peeling done in the winter has cost $1.50 per cord. The sticks are 4 feet long and range in size from 1 inch to 5 inches. Above this size sticks are split. Splitting costs about $1 per cord. Of late years willows have become so scarce in several of these localities that considerable material has been imported from a distance, and often the companies have paid the transportation charges, giving the mill prices for cordwood delivered at the nearest railroad point. No distinction is made between the different species of willows, as any willows of the desirable size seem to produce a high grade of charcoal.

PULP.

Willow wood is used to a limited extent for paper pulp, although its short fiber makes it useful only as a filler for the longer fibered woods. In the North, where most of the paper mills are located, willow does not occur in sufficient quantities to be given any particular attention. In the South, however, along the lower Mississippi and its tributaries, there is a good deal of willow which is not large enough for saw timber but would be suitable for pulpwood. On many thousands of acres trees from 5 to 15 inches in diameter form dense stands. These could for the most part be logged and transported

to a mill with great economy. The willow could be mixed with longleaf pine, which has very long fibers and which is coming into use in the South for pulp.

Should willow become important in that region for pulp, black willow on the Mississippi bottoms offers ideal conditions for practicing forest management. The tree grows rapidly in dense natural stands and reproduces abundantly by seed or sprouts. The bottom lands are low priced and highly fertile, the growing season is long, transportation is cheap, and logging conditions excellent.

ARTIFICIAL LIMBS.

It is estimated that there are now in this country nearly 200 manufacturers of artificial limbs. The first artificial leg, other than the ordinary wooden pegs, is said to have been made in London by a man named Cork in the early part of the nineteenth century. Although very imperfect, this device was a great improvement over the old peg. The early name of "cork legs" was continued, and in time the public began to think that these legs were made of cork. The materials most commonly used are wood, leather, aluminum, fiber, or papier-mâché for the major parts and rubber and felt for the minor parts. The majority of manufacturers use some wood, usually willow. Of the species used the following are most common: White, yellow, crack, black, and peachleaf willows. In New York the yellow willow is the most commonly used, although both the white and crack willow are used occasionally. In the Lake States the white and crack willows are used the most, and are about equal in importance. The consumption of willow wood for this purpose offers to the enterprising farmer situated near a city a means of selling a portion of good willow trees at a fair price.

TRADE NAMES FOR SPECIES USED BY MANUFACTURERS.

The name "white willow" is usually applied to the sapwood of any willow and does not in the trade necessarily indicate the regular white willow, although it may. In Minnesota the crack willow is called white willow, as is also *Salix amygdaloides*, a common wild willow of that region, which is, however, seldom used. The wood called "white willow" in Minnesota is tough, full of knots, and hard to work. The wild willow, when it is used, generally goes into some part that does not come in contact with the body. It is considered heavier, more porous, and stronger than the wood called "red willow." The white willow of Missouri is *Salix amygdaloides* and is also known to the trade as swamp willow. The so-called imported English willow is all grown in the United States, but is doubtless from the species *Salix alba*, which is the English white willow. The Pennsylvania red willow of the trade is also *Salix alba*, and in this region the wood seems to be more reddish than farther west.

The wood of finest appearance is from the southern black willow, which comes in the market in two forms, the black and red heartwood. In the south the willow grows to be a forest tree, often with a clear length of over 50 feet, from the heartwood of which it is possible to cut a good many bolts large enough, even when quartered, for any requirement. The wood is clearer than the other species, and although several manufacturers declare it to be less tough and durable, it is very little, if any, inferior, provided it is cut at the proper time and thoroughly seasoned.

CUTTING AND SEASONING THE WOOD.

The consensus of opinion among manufacturers seems to be that the wood for artificial limbs should be cut in the winter. All, however, do not agree on this point. One claims that willow blocks cut in July and properly handled are as good as any he ever used. Most manufacturers consider it necessary for the wood to season for from one to three years, although an occasional exception to this rule is found. The trees used are generally large enough to allow the log sections to be quartered and still be 6 inches or over through the section. This would take a tree 12 inches or over in diameter. In a few cases the wood from smaller trees is used. Round blocks are not desirable, however, being apt to check because when they are worked the hollow portion generally corresponds too nearly to the annual rings. Only a very small portion of a tree cut for this purpose is utilized. Since the blocks must be quartered from straight logs free from knots, the average willow tree, especially when grown in the open, furnishes less than 10 feet of merchantable material. Trees that yield but one 4-foot section are often cut. The bark is generally removed at the time of cutting and splitting, but it may be left on the sticks until they are ready to be worked up. It is desirable to split the logs as soon as they are cut, as, otherwise, they may so check in drying as to spoil a portion of the wood. Many manufacturers also paint the ends of the sticks to prevent rapid drying and consequent splitting. It is also a common practice to bore a hole in the end for the same purpose. The wood is then stacked in a dry shed or left where there is a free circulation of air. The blocks are piled on dry wooden slats, so that they do not touch each other. Even after the blocks are treated in this manner there is often a loss of 10 to 30 per cent of the sticks, due to defects and rot.

The length of the blocks varies from 8 to 20 inches. The sticks are, however, brought in in 4, 6, or even 8 foot lengths and recut later. Many manufacturers cut their blocks in 16, 18, and 20 inch lengths. In diameter they range from 5 to 12 inches. Blocks 6 inches in diameter and 20 inches long weigh 9 or 10 pounds when dry. A block 5 inches in diameter and 16 inches long weighs about 7

pounds. It is claimed by some that sawed blocks are better than split blocks. Sawing the blocks would cost about 50 cents per 100 pieces.

The price paid for willow for this purpose varies greatly. Some manufacturers are able to buy fairly good material for almost cordwood prices. Others insist on higher class material and often pay several times as much for it, especially if it is brought from a distance. In Ohio 25 cents per block is paid for clear material averaging in size 5 by 5 by 16 inches. In Missouri fair material brings 50 cents a piece for pieces 6 by 6 inches by 4 feet and up. Fairly good wood may also be bought for $8 to $12 per cord. In Minnesota select wood brings $30 to $75 per thousand feet, board measure, or $15 to $30 per cord. In New York the price ranges from 15 cents to $1.50 per stick, according to the size and quality.

BASKETS.

One of the most important commercial uses of willows at present is for willow furniture and baskets. For this purpose over 3,000,000 pounds of peeled willow rods are used every year, approximately half of this amount being grown in this country. Willows so grown are more of a farm than a forest crop. As a forest crop, they would be termed a system of coppice on a one-year rotation. Occasionally they are grown both for basket making and to protect the land they occupy from the ravages of floods. The crop may thus be made to pay for the labor involved in the planting and the protection afforded is often of great value. The principal species used in basket-willow culture are American Green, Purple, Lemley, and Patent Lemley, and to a smaller extent the Caspian willow. All of these are European species. Other European species such as the White Osier (*Salix viminalis*), which grow splendidly there, have not been successful in the United States. None of the native American species of willow are at present cultivated for basket-making purposes. Several species growing wild have, however, been used to a considerable extent locally. Chief among these species are the sandbar willow (*Salix fluviatilis*) and shiny willow (*Salix lucida*). The Forest Service is at present making a trial of the native species for basket-making purposes. Though it is too early to predict the outcome of these experiments, it can be said that a number of these species give evidence of being satisfactory basket willows. Further information in regard to basket-willow culture is contained in Farmers' Bulletin 622, "Basket Willow Culture."

POSTS.

There are many species that make better posts than willow, but in treeless regions and even in the better timbered localities its value should not be overlooked. Well-seasoned posts of the black or white

willow set in dry soil often last five to seven years. In soils that are alternately dry and wet and which freeze and thaw a great deal, willow posts are shorter lived, but under such conditions the life of any kind of post is much shortened. Posts of the diamond willow (*Salix cordata*) are very durable. More willow than cottonwood posts can usually be produced on a given area in a given time, especially if the trees are planted in rows, and willow posts are generally set in preference to cottonwood.

Willow wood is light, fairly porous, and quite easily treated. A treated willow post is practically as good as a treated post of any other species and much more durable than an untreated post of most species. Where good cedar, catalpa, locust, or Osage orange posts are obtainable for 20 to 30 cents, it would scarcely pay to use treated posts, but in many parts of the Middle West the average price of a red cedar post is approximately 40 cents. At this price it would be economical to use treated willow posts. First-class willow posts can be grown on good farm land for 12 cents apiece and second-class posts for 8 cents. These can be treated at a cost of 10 cents. Including the cost of peeling at 3 cents each, the cost of first-class creosoted posts is 25 cents and second-class posts 21 cents. Willow posts should be seasoned 8 or 10 weeks before being treated. Round posts are better for this purpose, as the penetration is better in sapwood than in heartwood. A willow post properly treated should last from 12 to 20 years. There seems to be a decided difference in opinion as to the value of seasoning untreated willow posts. At one experiment station it was found that usually seasoning was of little importance, but experience elsewhere does not altogether corroborate this observation. At Iowa Falls, Iowa, willow posts cut in the winter, seasoned with the bark on, then peeled and set out the following autumn, have had an average life of 10 years. At the same place willow posts cut in June and set out immediately lasted only 2 or 3 years. At numerous places in the prairie region seasoned willow posts have lasted 10 years, while most reports of decay in a short time also show that the posts were not seasoned. In setting willow posts care should be taken to avoid using material with doty heartwood. It may easily escape notice because the heart of willow shows very little discoloration until decay is far advanced.

TANNIN.

Willow bark is an important source of tannin in Europe, especially in Russia, France, Denmark, and Germany. In Russia it is used in the preparation of the finest leather, and combined with birch tar oil it produces the well-known scent of Russia leather. Von Höhnel states that the crack willow (*Salix fragilis*) and basket willow (*Salix viminalis*) are the best for this purpose, containing 12 to 14 per cent

of tannin, while other species contain 6 to 11 per cent of tannin. H. G. Bennett in "The Manufacture of Leather" asserts that crack willow and *S. arenaria* contain 7 to 11 per cent of tannin and are commonly used. Alexander Watt in "Leather Manufacture" states that the bark of white willow (*S. alba*) and *S. cinerea* is used for tannin in France.

Tests made by the leather and paper laboratory of the Bureau of Chemistry of willow bark collected in 1914 at Arlington, Va., by the Forest Service, produced amounts of tannin as follows:

TABLE 16.—*Tannin in willow bark.*

Species.	Per cent total dissolved solids.	Per cent soluble solids.	Per cent nontannins.	Per cent tannins.	Number of samples.
S. nigra (trunk)	16.16	15.10	8.38	6.71	11
S. alba (trunk)	18.13	17.03	9.40	7.63	11
S. fragilis (trunk)	23.32	22.27	14.12	8.49	12
S. fragilis (branches)	19.62	18.04	9.64	8.40	9

Hemlock, chestnut oak, Spanish oak, black oak, hickory, and chestnut wood range above willow in tannin content, but in some cases the high tannin content is offset by the difficulty of securing or handling the bark.

The bark left in the woods in the making of excelsior and the peelings from basket willows, of which a large amount is often collected in one place, could be utilized at a low cost. If manufacturers of tannin extract could be interested in willow bark and assured of a sufficient supply, a profitable industry might be established.

OTHER USES.

Willows, because they produce flowers from which a high grade of honey can be obtained, have long been recognized as a useful bee plant, especially in early spring. Many beekeepers have set out willows especially for this purpose. Great care should be exercised in such planting to make sure that the cuttings are from staminate trees, as the pistillate flowers are of little value as a bee food.

In New Jersey, Delaware, and eastern Maryland willow is used for berry props and poles in truck gardening. For this purpose it is only fairly durable, but it is cheap and easy to secure.

The freedom of willow wood from checking and the ease with which it is worked make willow desirable as a carving wood and for picture frames, wooden shoes, and woodenware, such as bowls, scoops, ladles, and trays.

F-80658

FIG. 1.—POLLARDING WILLOWS FOR CHARCOAL WOOD USED IN MANUFACTURING OF GUNPOWDER.

Young healthy trees, beginning 2 years' growth after cropping. Wilmington, Del.

F-80655

FIG. 2.—POLLARD WILLOWS CROPPED THREE TIMES.

Trunks destroyed by injury due to floods and decay. Low stumps are more desirable in such situations. Wilmington, Del.

POLLARD WILLOWS.

F-12343A

FIG. 1.—A FIELD BADLY GULLIED AS A RESULT OF TOO HEAVY GRAZING.

F-369A

FIG. 2.—THE VIOLENT EFFECT OF A FRESHET ON LOOSE ALLUVIUM BANKS ON WHICH THE TREE GROWTH HAD RECENTLY BEEN REMOVED.

TWO PLACES WHERE WILLOWS COULD BE USED SUCCESSFULLY FOR PROTECTION.

USES OF WILLOWS FOR PROTECTION.

PROTECTION FROM EROSION.

The adaptability of willows to moist conditions and their rapid growth make them the best available plant for protecting soil from erosion by running water or wave action.

In Europe, especially in Russia, very definite methods have been worked out for protecting soil from gullying and for the building up and improvement of gullied fields. In this work willows have been largely used and have given the best results obtained from any of the numerous species tried. In this country farmers are just beginning to realize the importance of such protection and improvement work. Thousands of acres of abandoned fields would still be productive if proper preventive measures had been taken to check erosion. To the farmer who sees great holes gouged into his fields and the fertile top soil washed away from the land the question of devising some means of checking this devastation is of vital importance.

Most owners fail to appreciate the danger and allow the erosion to continue until the damage is done. Usually erosive action in a field is apparent first as sheet washing which is generally the forerunner of a gully. This can be stopped by the use of cover crops, judicious tillage, or in extreme cases by terraces and ditches. A gully already formed should be filled with brush, straw, or stone, or planted with some tree or shrub. It is surprising how fast a gully builds up when the bottom has been thickly planted with willows. They break the force of the current and catch and hold the sediment. This process would kill most trees, but the willows are able to survive and to eliminate a gully in a few seasons. The tree growth may then be removed so that farm implements can pass over, unless danger of a recurrence of the gully makes it necessary to keep the area in sod.

For the protection of stream banks willow plantations are generally the most effective, although cottonwood may also give good results. The best species to use are the vigorous growing wild ones found in the vicinity. Where native willows are not readily available, the white, yellow, crack, or weeping willow should give good results. Cuttings of any of these can be obtained cheaply from the various nursery dealers. The use of trees in the protection of stream banks is necessarily confined to creeks and small rivers and only to those having a medium velocity. Tree planting is generally without avail on caving banks of very swift streams, especially if the soil is loose, as it is also without avail along the large rivers even if they are not swift. These are problems for an engineer, although at the beginning the caving of a bank can often be prevented by proper treatment of the tree cover at dangerous places. Planting can be done success-

fully, however, along the smaller streams that in the aggregate destroy large areas of the richest land.

There are often places where floods have left perpendicular banks of soft soil, which, being constantly undermined by the current, cave in from time to time. It is very important that such places be protected, for such a bank is a constant menace to all the land lying back of it in the valley. Mechanical means of protection are generally expensive and are often not permanently effective. A good method of protecting soft alluvial banks is to make them sloping instead of perpendicular. This may require considerable grading, but it is absolutely necessary. After the bank has been reduced to a slope, the less precipitous the better, the face of it should be thickly planted with willow cuttings. For this purpose any willow material available in the vicinity is suitable. Cuttings from 1-year-old shoots up to stakes several inches in diameter will grow vigorously. In the more exposed places, especially near the water's edge, the larger sets are more satisfactory as they are less liable to be washed out before they have become firmly rooted. Willow is often more serviceable than walls of masonry, and the facility with which it is reproduced by seed, suckers, sprouts, and cuttings, both naturally and artificially, makes it both inexpensive and effective.

In places where conditions are more severe the following procedure has been successful:

Green willow poles 18 to 20 feet long are cut in the spring before growth begins; the poles are laid on the ground near the bank 2 or 3 feet apart with their butts toward the stream; woven wire fencing is then securely fastened to the poles, leaving 2 or 3 feet of the poles projecting below the wire if the margin of the stream is of soft mud and less than that if the bank is firmer. Sections of wire about 100 feet long can be handled to the best advantage. After the wire has been fastened to the poles, they are all pushed over the bank together so that the butts of the poles fall and sink into the soft mud at the water's edge. As the banks cave off some of the soil lodges on the wire, partially burying and weighting down the poles, which take root and grow. The wire serves to hold the mass of willows together until they have been firmly rooted. The ends of the wire are made secure by small wire cables running back up the bank and each one held by a "deadman." The caving and erosion of the bank soon round off its top edges and the growing willows catch and hold the soil, giving the bank the proper slope to resist erosion. Planting a few cuttings farther up the bank to hold this slope is often advantageous. This method can be varied by driving shorter posts firmly into the soil at the water's edge, but leaning somewhat toward the bank, and then attaching the woven wire. This holds the soil as it caves off, and as a slope is established it is planted with cuttings.

Another method which has been used to good advantage at the bends of small streams is to drive willow stakes 2 to 4 inches in diameter into the bank upward from the water's edge at low water and quite close together and to fill the spaces between them with loppings from willow trees or brush of all sizes, of which as much as possible is made to touch the ground or is partially buried. Additional forked stakes are useful in making the brush secure. This procedure insures a growth of willows that will protect the bank from further erosion.

In all operations for bank protection it is important to remember: (1) That a perpendicular caving bank must be made sloping before planting can be effective; (2) that planting should begin at the water line and proceed away from the stream; (3) that mechanical aids are often necessary to create conditions where planting can be done effectively; (4) that any part of a live willow and (usually) a cottonwood will grow vigorously if placed in moist soil.

BANK REVETMENT.

Willow is largely used in the making of mattresses for bank revetments along the lower Mississippi River and its tributaries. In one district alone, in 1913, 145,847 cords were used. The total amount of willow used for this purpose is from 300,000 to 400,000 cords per year. The trees are largely sandbar, peachleaf, or black willow, and are small, ranging from 1 to 5 inches in diameter and from 25 to 40 feet in length. In the New Orleans district cull lumber is used for the mats. This is partly because willows are not quite so plentiful in the lower portion of the valley and partly because the different districts working separately developed somewhat different methods of dealing with bank protection. Of the three species most commonly used the sandbar willow is the best. It is of slower growth than the other species, but it comes up in very dense stands and grows very straight. In thick stands it is practically free from branches except for a small crown. The habit this species has of sprouting prolifically from the roots insures a heavy stand when once started. The wood is slightly heavier than the other willows and somewhat tougher and stronger. Practically speaking, there is little difference in species, and contractors pay less attention to species than to size and form.

The plentiful supply of willows has heretofore made their cost simply that of cutting and transporting them. In the last few years, however, the willows in the immediate vicinity of some of the larger revetment works have become so scarce that from $1 to $2 per acre has been paid for the privilege of cutting over private lands. The best willows come from the lower sand bars and islands. Willows growing above the 35-foot stage of the river are seldom used, both on account of the expense of getting them to the water and the fact that they are seldom of the right quality, being generally crooked and

branchy. In 1913 the contractors received $1.50 to $2 per cord for the willows loaded on barges, and at this price they were in some instances able to make wagon hauls of a mile and still operate at a profit.

The first cutting is sometimes 10 or 12 years old, although willows 8 or 9 years old are most commonly used. On cut-over land the new crop is ready in 7 years, and in several places in lower Missouri three crops including the original seedlings have been grown and cut off in 25 years' time. The average yield of fully stocked stands (and most of the stands are fully stocked) is 40 cords per acre, although it may range 10 cords above or below this figure on small areas. The original seedlings at this rate produce an average of 4 cords per acre per annum; and the sprout growth, between 5 and 6 cords per acre per annum. These figures represent the maximum capacity of the land, complete utilization, and a low solid content per cord. It is doubtful whether the trees at this age reach their maximum production, but the increased production obtained by a longer rotation would be offset by the less close utilization that would be necessary if the material went into cordwood for excelsior, pulp, or fuel.

The land on which these willows are found is usually a rich sandy silt, although here and there occur patches of less fertile sands on which the growth is not so vigorous. This land, fertilized by a deposit of sediment each year, is rich enough to produce a relatively high yield of any kind of crop if it could be farmed. On poorer land, even if moisture conditions were favorable, it is doubtful whether more than one-half to two-thirds of this yield could be obtained.

The use of willows by the Army engineers has so far been for the manufacture of channel, pocket, and facine mattresses. To make these mats, they have developed especially built machinery and barges, so that in recent years the cost has been much reduced. The mats are usually 1,000 feet long, 250 feet wide, and 12 to 14 inches thick. The dimensions, however, vary considerably in accordance with the requirements of the situation. After sinking the mat along the bank, the upper portion approximately at low-water mark, the bank is graded with a hydraulic grader to a slope of 1 to 3 and paved with rock varying in size from 4 to 100 pounds. (See Pl. VII, fig. 2.) The cost of making the mat varies considerably, but on the average is from $4 to $8 per square (a square is 100 square feet), or $10 to $20 per linear foot. The completed work, including the mattress, grading, and paving, costs $20 to $30 per linear foot. The mats will last for 30 years, or longer under favorable conditions. Portions of the mat exposed at intervals of low water have a tendency to disintegrate very quickly unless buried

F-16782A

FIG. 1.—WEAVING A WILLOW MAT. SLOUGH NECK LANDING, TENN.

F-16785A

FIG. 2.—REDUCING THE BANK TO THE PROPER GRADE WITH THE HYDRAULIC GRADER. SLOUGH NECK LANDING, TENN.

BANK-REVETMENT WORK.

F-16787A

FIG. 1.—THE MAT AS IT NEARS COMPLETION, 1,000 FEET LONG AND 250 FEET WIDE.

F-16792A

FIG. 2.—SINKING THE MAT BY THROWING ROCK BALLAST ON IT.

BANK-REVETMENT WORK.

F-38260

FIG. 1.—WILLOWS COMING IN NATURALLY AND GRADUALLY BINDING TOGETHER THE SHIFTING SAND DUNE. NEAR MICHIGAN CITY IND.

F-38301

FIG. 2.—WILLOWS AND POPLARS WORKING DOWN TO THE EDGE OF LAKE MICHIGAN. MICHIGAN CITY, IND.

WILLOW AS A SAND BINDER.

F-16114A

TYPICAL WILLOW ROW IN PASTURE. DENSE FOLIAGE ABOVE REACH OF STOCK. (CRACK WILLOW.) AGE 30 YEARS. WILLIAMSBURG, IOWA, 1913.

in the mud and sand. In sinking the mat into position stone is used. This process is shown in Plate VIII, figure 2.

Table 17 shows, as near as it is possible to obtain the figures, the annual amount of willow used in revetment work. Where annual figures are not available, the average amount used for several years is given. Approximately 5 per cent of the amount is cottonwood or other species.

TABLE 17.—*Amount of willow used in revetment work.*

	Cords.
Missouri to Ohio River, average of 3 years	25,000
Missouri River, Fort Benton to Kansas City, 1913	12,000
Missouri River, Kansas City to mouth, 1913	43,580
Mississippi River, St. Paul, Minn., to Missouri River, average of 4 years	100,000
Mississippi River, Cairo, Ill., to White River, Ark., 1913	48,360
Mississippi River, White River to Warrington, Miss., 1913	51,633
Mississippi River, Warrington, Miss., to Head of Passes, 1913	53,350
Mississippi River, South and Southwest Passes, average of 4 years	23,330
Arkansas and White Rivers	900
Total	358,153

WILLOW AS A SAND BINDER.

One of the most important uses of willows is for binding shifting sand. Along the Atlantic coast and the Great Lakes, and to a lesser extent along the Pacific coast, there are large areas which are being reclaimed or will be reclaimed as land becomes more valuable. On the eastern shore of Lake Michigan considerable work has been done and more should be undertaken, as the dunes are moving in in many places and covering valuable farm land. Plate IX shows a dune being reclaimed naturally by willows and an older portion where poplar has followed the willows. Ordinarily it is customary to start grass first in such places, but where conditions are favorable willows can be started without this preliminary step. In Russia large areas have been reclaimed, principally by means of the Caspian willow (*Salix acutifolia*). The willow is very successful where brush is available and can be scattered over the sand areas as a temporary shelter under which it may gain a foothold before being subjected to the full force of the wind. On the Pacific coast loose straw was thrown on the land, and although the wind was very strong a surprisingly large amount was not blown away. Such a planting, however, to be effective must begin on the lee side of a body of water or strip of timber or some object that prevents the blowing of the sand upon the planting to any appreciable extent. Planting begun in this way can be continued out over the shifting area indefinitely with little chance of failure. It is, however, worse than useless to attempt to plant up an area which has adjacent to it on the windward side a body of loose sand.

The native species are best adapted to this purpose. In all the regions mentioned there are to be found growing wild, even upon the sand, willows with which better success can be had than with imported species. The basket willow can not be recommended for this purpose, although in the less exposed and more fertile places they would perhaps grow very well. The white, crack, and yellow willows make a very thrifty growth in the sand where conditions are not too severe. Of the native species the black willow, the sandbar willow, and the laurel willow grow well in such situations.

The cuttings should be from 12 to 18 inches long, the length depending somewhat on how much the sand dries out during the dry season. The rows should be run perpendicular to the direction of the prevailing winds, and from 6 to 12 feet apart, the distance depending upon the slope and the intensity of the wind. The steeper the slope the closer the rows should be. The cuttings should be planted in the rows and as closely as possible.

WINDBREAKS AND SHELTER BELTS.

For windbreaks and shelter belts in the central prairie States there has been no more widely used tree than willow. When the settlers came into these States they immediately saw the necessity of providing shelter around the farm buildings and planted such quick-growing species as willow, cottonwood, and soft maple, willow predominating. The stock was easily obtained, easily planted and required the minimum of care. The returns from these plantations have been good considering the treatment given them. Many are now dead or decadent and the question is what to do next. The wise settlers have underplanted their willow groves or started other species to replace them. The majority, however, overlooked this important matter.

For starting a grove or windbreak in the prairie region there is probably no better tree than the willow. It grows rapidly, is fairly long lived except on dry clay soils, has a fuel value on the farm, and reproduces vigorously from the stump. The green ash or white elm are more valuable, but generally should follow the willow on a barren farm. Cottonwood as a windbreak or as a nurse tree is no better than willow, but occasionally even on the prairies it produces a fair grade of rough lumber, perhaps better than willow. Because of its branching habit, its lack of clear length until the tree becomes quite large, and its fairly heavy foliage the willow is not surpassed by any other broadleaf tree in the protection afforded. Willows can also be thinned heavily with the assurance that sprout reproduction will rapidly take the place of the material cut out. In fact, such thinning is beneficial to the windbreak, as the foliage is kept low and dense, and cutting back will often keep the row vigorous for from 40 to 50

years, whereas if the cutting is not done each plant develops one to three large trunks which in from 20 to 30 years reach maturity or are broken, the vigor of the original tree being thus practically destroyed. The capacity of a willow tree to put out vigorous sprouts begins to decline somewhat at the age of from 20 to 30 years, depending upon the soil and moisture conditions, but it never entirely passes away. If the willows are to be considered permanent, they should be cropped in periods of 8 to 10 years, either by gradual or clear cutting. At the first evidence of decreasing vigor new trees should be set out and the first ones cut as soon as the second planting is large enough to be effective. Ordinarily the willows should be considered a temporary shelter or a nurse crop and provision made for the establishment of conifers or of the better hardwoods to take their place.

PLANTING WILLOWS.

SOIL REQUIREMENTS FOR WILLOW PLANTING.

Willows grow best on a moist, rich, well-drained sandy loam. They will, however, tolerate a considerable variation of these conditions and still make a reasonably satisfactory growth. They will grow faster for the first 25 years than any other of the northern broadleaf species, with the exception of cottonwood, on any but the driest soil. They endure excessive moisture conditions better than cottonwood. Willows are not sensitive either to acid or alkaline soils, but a poor growth can be expected on soils where either of these conditions is very pronounced. Willows prefer land that is flat or nearly so, but they grow well on any slope where the other conditions are favorable. The adaptability of willows makes them particularly a waste-land species, but their greatest superiority shows itself in plantations on overflow land in the vicinity of streams.

SPECIES FOR PLANTING.

In the North undoubtedly the best willow species for planting is the crack willow. Its rapid growth, upright form, and freedom from side branches or water sprouts when fairly closely planted make it superior to every other. Many plantations in the treeless region have been of this species, although generally reported as white willow. The second best species is the white or yellow willow. In sheltered positions the weeping willow will grow almost as fast as the crack willow, but if exposed will be broken up by the wind at an early age. While it is possible for the weeping willow to produce almost as much fuel as the crack willow, the form of the tree makes the material it produces of little value for anything else. The weeping willow recommends itself over the crack willow only for situations where its particularly striking and beautiful foliage can be made

effective in the improvement of the landscape. Throughout the North the black willow is a smaller tree than the white or crack willow, and for this reason inferior to them. As a tree for planting it is not recommended except in places where the main consideration is the protection to be afforded, rather than the material produced. Under these conditions the black willow is very desirable, as it can usually be secured in the vicinity at little cost.

In the South the same recommendations hold good except for black willow. The lower Mississippi Valley is the region of best development of this species, and its rapid growth and large size make it doubtful whether either crack or white willow would be superior to it. No records of the growth of crack or white willow in the region are available, and until they are preference should be given in planting to the black willow, at least on bottom land.

CUTTINGS.

MATERIAL.

Willows are more easily planted than any of the other commercial tree species of the United States. This is due to the fact that cuttings can be gathered and planted as cheaply as seed of most species, and the first year's growth of cuttings is equal in vigor to that of 1-year-old seedlings. As compared with 1-year-old seedlings, cuttings are much less expensive. Cottonwood can also be propagated by cuttings, but they are generally less easily secured wild, are more expensive if purchased, and unless rooted or calloused suffer a much greater mortality when planted. Under unfavorable conditions uncalloused willow cuttings will start where cottonwood fails completely. Willow cuttings can be obtained for $1 to $1.50 per thousand. When large quantities of cuttings are desired and there is no particular hurry about getting them planted, a few cuttings planted in a row in the garden will supply the necessary planting material. The Forest Service furnishes a list of dealers from whom willow cuttings may be purchased.

SIZE OF CUTTINGS.

The cuttings should be obtained from healthy, vigorous plants, the size of the cutting depending upon the kind of crop desired and the conditions under which it is to be grown. If the plants must establish themselves in competition with other species, such as scrubby willows, the cuttings should be larger than where the plantation is to receive cultivation. In open spaces, especially those which can be cultivated for a year or two, cuttings of a foot in length can be used to advantage, and these after the first or second year will be abundantly able to take care of themselves, although cultivation for a longer period, if it could be done economically, would increase the growth consider-

ably. In general the smaller the cutting, if protected from mechanical injury, the less chance for disease. The best size for average conditions is about 16 to 20 inches long and from one-half inch to 1½ inches diameter. In the method known as "pollarding," sometimes employed in willow growing, the cuttings are made 8 to 10 feet long and from 1 inch to 3 inches in diameter from branches or shoots ranging in age from 3 to 5 years. These at the end of the first season present the appearance of a small tree with an 8-foot clear length, and when planted under unfavorable conditions are much more able to compete successfully with other species. However, this high-coppice system has its drawbacks. Such plants with a strong growth of sprouts produced 8 feet from the ground on a poorly rooted trunk give an excellent opportunity for serious injury. The wind alone is often sufficient to sway it enough to break the small new root system. If this occurs in the middle or the latter part of the growing season, it generally kills the plant. There are certain conditions, however, that may make the pollard system advisable. When the trees are to be planted in situations where they are likely to be periodically inundated, it may be better to have the limbs produced above the reach of the flood if there is no débris or ice to cause serious injury to the trunk. Where animals must be allowed to graze on the land it is better to have the sprouts above their reach, as they not only browse the tender branches but do further damage by tramping and breaking off the limbs. High coppice is also desirable where the land is to be cultivated between the rows of willows, as the production of a sprout growth from the ground would take up so much room that there could be no economy in growing the two crops together. This is the chief reason why pollarding is resorted to in many parts of Europe. Such a crop practice is little used, however, in this country.

The low coppice has the important advantage that it gives a chance for the individual sprouts, especially if they come from the region of the root collar, to form roots of their own so that the life and health of the sprout is not necessarily dependent upon the old trunk. It has been observed that in many instances where a low coppice system has been employed the original trunk has completely decayed but the surrounding sprouts have formed root systems of their own, from which they receive support and nourishment. Low coppice makes possible an indefinite regeneration of the tree, while the high coppice requires periodic plantings.

AGE OF CUTTINGS.

The cuttings should always be made from young, vigorously growing wood. If old wood is used a smaller number of the cuttings will start and the growth at first will be less rapid. The cuttings from old wood do not start as quickly after planting as do those from young

shoots. The reason for this is that on 2-year-old sprouts there are frequent buds ready to start growth at once, while on older wood the buds and shoots must start after the cutting has been planted and the growing season has commenced. Another advantage of the young sprout is that it is generally free from branches and thus easier to prepare and plant. Under less favorable conditions it is necessary to use cuttings from 2 to 5 years old. When it is known that willow cuttings are to be used the following year, it is a good plan to cut off limbs of small trees the year before in order that suitable material for planting may be produced. A little forethought in this matter will often make the purchase of material from dealers unnecessary, although the grower should make sure that he is planting the right species.

TIME AND METHOD OF MAKING CUTTINGS.

The cuttings can be prepared any time after the wood is well ripened in the fall, but in the Northern States the best time is in February, as this gives the cuttings a chance to callous before being set out and at the same time does not necessitate leaving them in storage long enough to become damaged. Cutting can be done with a large knife, a hatchet, a saw and miter box, or with large pruning shears. The cutting should be made smooth and clean. The small saw and miter box is a very rapid method but is likely to tear the bark from the wood, thus injuring the cutting. With a large pruner several sprouts can be cut at once without crushing the bark unless the sprouts are resting on top of each other. In the preparation of larger cuttings an ax or saw must be employed. The ax is preferable. It is best to plant large cuttings as soon as prepared, as they are not easily stored.

STORAGE AND SHIPMENT.

It is often advisable to prepare cuttings a considerable length of time before they can be planted. In such a case it is necessary to provide a suitable place for storing them. A cool dark cellar is ideal for this purpose, since at all times of the year growth is less likely to start there than in other places. The cuttings should be buried in an upright position (the buds pointing upward) in moist sand. Moist earth can be used, but it is not so satisfactory as sand. When no other place is available, cuttings can be heeled-in in pits in the open. The top of the pit should always be covered. Cuttings stored in this manner are likely to start early in the spring, and for this reason they should be carefully watched.

METHOD OF PLANTING.

In establishing a plantation of willows the amount of preparation to be bestowed upon the land is dependent upon its condition. Land well situated and free from other woody plants and rocks should

be thoroughly plowed. If this can not be done and the cuttings must be planted among bowlders, among other trees, or in brush, clear spaces should be selected wherever possible or the brush should be lopped back in order to give the cuttings a chance to start. Once started, the willows soon outstrip the brush and eventually kill it by shading.

All planting should be done in early spring. How deep cuttings should be planted depends somewhat on their size. In planting for low coppice crops, a 12-inch cutting should be buried almost its entire length, leaving but 1 or 2 inches exposed. This portion should possess one or two buds. When longer cuttings are used, the depth should be 12 to 15 inches. Pollard sets should be planted about 18 inches deep. For making the holes to plant small cuttings a sharpened iron bar may be used, but for the larger cuttings a spade is necessary. In every case the soil should be packed firmly around the cutting.

The spacing of the cuttings is dependent upon the kind of land to be used and the crop desired. If the land is clear, a regular interval can be employed, but on steep slopes and among brushy or rocky obstructions it is better to plant wherever a favorable spot can be found or made. If a regular interval is employed and lumber is desired, the cuttings are planted 6 by 6 feet or 1,210 plants per acre. Thinnings are made at the end of 8 or 9 years, reducing trees to half the original number, and at the end of 16 or 20 years, reducing the number of trees to about 300 per acre. The material taken out can be used for charcoal wood or for fuel. At the end of 30 or 40 years the land should be stocked with at least 150 trees, most of them of suitable size and shape for willow lumber. However, the majority of willow plantations in this country will be intended for fuel, paper pulp, or posts, and for these purposes it is better to plant about 5 by 5 for a 6 to 10 year rotation and 6 by 6 or 8 by 8 for a 12 to 20 year rotation.

COST OF PLANTING.

Under most conditions willow plantations can be established more cheaply than plantations of any other species. Cuttings are used in all cases. It is well to prepare the land before planting by a thorough plowing, disking, and harrowing. This costs from $1.50 to $3 per acre. If the land is pasture land or an abandoned field, some work in brush or tree removal is often necessary. This costs up to $3 per acre. If a greater expense than this is necessary it is advisable to clear the land for plowing. In such cases it is best to destroy the brush cheaply, by burning, for instance, and then planting in spots wherever possible. By this procedure the cost of plowing is eliminated but the cost of planting is correspondingly increased. Cuttings for planting can be made for 50 cents per thousand and can be

purchased for $1 to $1.50 per thousand. Planting is best done by a man and a boy. If the man makes the holes with a sharpened iron bar and the boy drops in the cuttings and firms the soil, they should plant 2 to 3 acres per day with a spacing of 6 by 6 feet, or 1,210 sets per acre. Allowing $2 as wages for the man and $1 for the boy, the cost of planting is from $1 to $1.50 per acre. Cultivation for the first two years consists in disengaging the willows in the planting spots on unplowed land and in horse cultivation on plowed land. This costs from $2 to $6. Table 18 gives the range in cost of establishment of a willow plantation.

TABLE 18.—*Cost per acre of making a willow plantation.*

	Minimum.	Maximum.
Preparation of soil:		
Brush clearing		$3.00
Plowing or preparation of planting spots	$1.50	3.00
Stock (cuttings)	.50	1.50
Planting (man and boy crew)	1.00	1.50
Cultivation (first two years)	2.00	6.00
Total	5.00	15.00

CULTIVATION AND CARE.

If the plantation is a haphazard one, planted among bowlders, stumps, or in uncleared land, it can not, of course, be systematically cultivated. However, a little care in such a place will probably pay better returns than anywhere else. The young plants are very likely to be crowded out the first year or two if they do not have a fair amount of room, and a little cutting back of other growth will often save many young trees. In regular plantations on cleared land the ground should be plowed between the rows about three times the first year, twice the second year, and perhaps once the third year. Subsequently the shade of the willows will be sufficient to kill most of the weeds and to prevent excessive evaporation from the soil. Cuttings which fail to start should be replaced the same season if possible. In close plantations it will be necessary to plant longer cuttings than the original ones to prevent shading out. Allowing the fail places to remain unplanted reduces the productivity of the land. All diseased material should be removed as soon as noted.

CUTTING.

The best time for cutting is in late winter or early spring, but it should be finished before the buds start to swell. Fall cutting is next best, but it may result in the frost separating the bark from the wood at the stump, which injures its ability to sprout. Wood that is to be peeled should be cut in summer. Where sprout reproduction is desired, the bark should be cut through around the stump, so that when the tree is felled the bark will not be torn away.

COST OF GROWING WILLOWS.

Table 19 gives the cost per cord of growing willows on land of different values, with different costs of formation, low, average, and high yields, and different rotations. In this table compound interest at 6 per cent is charged on the land value, the cost of formation, and taxes. With a cost of formation of only $3 and a high yield the actual cost of growing a cord of willows on land valued at $5 per acre is 20 cents. Such a combination of conditions is exceptional, however, and would rarely be encountered. A poor yield from land valued at $100 and a cost of formation of $15 makes the cost of growing a cord from $5.95 to $7.64, depending upon the rotation. Except where the wood lot has a decided value for other purposes than the wood crop itself the plantation is not justified by the returns. Leaving out every other consideration except the value of the material produced, it is poor business to grow willows when the cost is greater than $2 per cord. This practically eliminates the use of $100 land for such a purpose unless a yield of 5 cords per acre is assured.

TABLE 19.—*Cost per cord of growing willows.*

$5 LAND.

Rotation—years.	Formation, $3.			Formation, $5.			Formation, $7.50.			Formation, $10.			Formation, $15.		
	Yield in cords.														
	5	3½	2	5	3½	2	5	3½	2	5	3½	2	5	3½	2
5	$0.24	$0.34	$0.60	$0.35	$0.49	$0.87	$0.48	$0.69	$1.20	$0.61	$0.88	$1.54	$0.88	$1.26	$2.20
10	.20	.29	.50	.27	.39	.68	.36	.52	.90	.45	.64	1.13	.63	.90	1.57
15	.20	.29	.51	.27	.38	.67	.35	.50	.87	.43	.61	1.07	.59	.84	1.47
20	.22	.32	.56	.29	.41	.72	.37	.53	.92	.45	.64	1.12	.61	.87	1.52

$10 LAND.

5	$0.32	$0.45	$0.80	$0.43	$0.61	$1.06	$0.56	$0.80	$1.40	$0.69	$0.99	$1.73	$0.96	$1.37	$2.40
10	.29	.42	.73	.36	.52	.91	.45	.65	1.13	.54	.78	1.36	.72	1.03	1.80
15	.31	.45	.78	.38	.54	.94	.46	.65	1.14	.54	.77	1.34	.70	1.00	1.74
20	.35	.51	.88	.42	.60	1.04	.50	.71	1.24	.58	.83	1.45	.74	1.06	1.85

$25 LAND.

5	$0.55	$0.79	$1.39	$0.66	$0.95	$1.66	$0.80	$1.14	$1.99	$0.93	$1.33	$2.32	$1.20	$1.71	$2.99
10	.57	.81	1.42	.64	.91	1.60	.73	1.04	1.82	.82	1.17	2.05	1.00	1.43	2.50
15	.64	.91	1.60	.70	1.00	1.76	.78	1.12	1.96	.86	1.23	2.16	1.02	1.46	2.56
20	.74	1.06	1.85	.80	1.15	2.01	.88	1.26	2.21	.96	1.38	2.41	1.12	1.61	2.81

$50 LAND.

5	$0.95	$1.36	$2.37	$1.06	$1.51	$2.64	$1.19	$1.70	$2.98	$1.32	$1.89	$3.31	$1.59	$2.27	$3.98
10	1.03	1.47	2.58	1.10	1.57	2.75	1.19	1.70	2.98	1.28	1.83	3.20	1.46	2.09	3.65
15	1.18	1.69	2.96	1.25	1.78	3.12	1.33	1.89	3.31	1.41	2.01	3.51	1.57	2.24	3.91
20	1.38	1.98	3.46	1.45	2.07	3.62	1.53	2.18	3.82	1.61	2.30	4.02	1.77	2.53	4.42

$100 LAND.

5	$1.74	$2.48	$4.35	$1.85	$2.64	$4.62	$1.98	$2.83	$4.95	$2.11	$3.02	$5.28	$2.38	$3.40	$5.95
10	1.95	2.79	4.88	2.02	2.89	5.06	2.11	3.02	5.28	2.20	3.15	5.51	2.38	3.40	5.96
15	2.27	3.24	5.67	2.33	3.33	5.83	2.41	3.45	6.03	2.49	3.56	6.23	2.65	3.79	6.63
20	2.67	3.82	6.68	2.74	3.91	6.84	2.82	4.02	7.04	2.90	4.14	7.24	3.06	4.37	7.64

In certain localities where there is a market for willow for gunpowder charcoal, or as excelsior wood, it would be profitable to grow willow when the cost of growing is $4 or under, since cut and peeled it is worth $7 per cord. Willow cordwood for fuel is not worth more than $4 in the prairie States, and as cutting costs $1.50 per cord $2.50 is the greatest cost allowable if a return of 6 per cent is to be received on the money invested. Under the conditions that have prevailed in the Middle West, where most of the willow plantations have been made, the average cost of growing has been from 50 cents to $1.50 per cord, estimated on the value of the land at the time of planting. To-day higher land values in this section of the country and higher costs make the probable average cost about $1.50 per cord. It should still be possible, however, to grow willows at $1 per cord on $25 land.

Many other considerations enter into the problem of determining whether or not it may be profitable to grow a tree crop on the farm besides the mere cost of growing the wood. The chief of these is the possibility of using labor at slack times. This may be worth more than the loss of 6 per cent on capital invested in the land. The value of the woodlot for protection and appearance must also be considered.

YIELD FROM WILLOW PLANTATIONS.

The yield from willow plantations varies greatly with the soil and moisture conditions and the care they have received. Planted on moist, well-drained bottom lands and kept free from the grazing of stock, willows will sometimes yields over 5 cords per acre. On short rotations where several crops are grown from sprouts the yield may, under exceptional conditions, reach 7 cords per acre per year. The average bottom-land plantation in which stock is allowed to run can not be expected to yield more than 4 cords per acre except on the most fertile soils. Willows planted in rows give slightly larger yields than in other plantations, even when due allowance is made for all the ground they cover. On an average they yield 20 per cent more than in a dense stand. This is no doubt due to the greater amount of light received on a given unit of space.

In the more moist situations on upland soil willows make a fairly good growth, and a return of 3 cords per acre from a well-managed plantation can reasonably be expected. On the dry situations the yield is not over 2 cords per acre. Willow plantations on upland soils show very quickly the bad effects of grazing, especially in the more open stands. In such plantations the yield is seldom more than 1½ cords per acre.

Table 20 gives the yields of average sample plots, the kinds of material, and its value for plantations in the Northern States. These groves were not selected and represent minimum returns rather than average returns.

TABLE 20.— *Yield and gross returns from crack willow plantations.*

UPLAND.

Locality.	Age of grove.	Average height of trees.	Area of plot.	Number of trees per acre.	Total yield per acre.	Estimated in cordwood.				Estimated in posts, stakes, and cords.								Value of posts and additional cordwood.	Cost of formation.	Net annual gain.
						Total yield per acre.	Average annual yield per acre.	Total value per acre at $4.	Average annual value per acre at $4.	First-class posts 4 to 6 inches.		Second-class posts 3 to 4 inches.		Stakes 2 to 3 inches.		Cords in addition.				
										Number.	Value at 12 cents.	Number.	Value at 8 cents.	Number.	Value at 5 cents.	Number.	Value at $5.			
	Years.	*Feet.*	*Acres.*		*Cu. ft.*	*Cords.*	*Cords.*													
Conde, S. Dak...	13	30	0.1	1,920	1,513.20	20.96	1.61	$83.84	$6.45	.....	.....	890	$71.20	1,430	$71.50	6.50	$32.50	$175.20	$20.88	$9.88
Elrod, S. Dak....	20	39	.1	1,510	2,716.60	34.50	1.73	138.00	6.90	1,390	$166.80	1,190	95.20	1,310	65.50	5.30	26.50	354.00	25.68	12.12
Warren, Minn...	21	30	.1	760	2,880.20	36.00	1.71	144.00	6.86	530	63.60	2,200	176.00	2,190	109.50	9.20	46.50	395.60	26.45	12.87
Averages...	.....	.....	.....	.....	.....	.....	1.68	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	11.62

BOTTOM LAND.

Milnor, N. Dak...	8	28	0.1	3,520	1,650.00	23.70	2.96	$94.80	$11.85	.....	.....	.....	.....	3,300	$165.00	10.60	$53.00	$218.00	$18.01	$22.49
Groton, S. Dak...	18	45	.1	1,290	4,837.50	60.99	3.39	243.96	13.55	3,870	$464.40	.....	.....	1,290	64.50	4.47	22.35	551.25	24.21	22.51
Canby, Minn.[1]....	20	53	.05	2,340	11,763.20	144.60	7.23	578.40	28.92	9,420	1,130.40	2,340	$187.20	3,480	174.00	3.80	19.00	1,510.60	25.68	55.26
Grafton, N. Dak..	20	42	.1	725	3,958.50	49.50	2.48	198.00	9.90	2,900	348.00	1,450	116.00	.....	.....	8.00	40.00	504.00	25.68	17.80
Tea, S. Dak.....	21	43	.1	1,330	3,657.70	47.50	2.26	190.00	9.05	2,270	272.40	920	73.60	470	23.50	4.10	20.50	390.00	26.45	12.67
Cottonwood, Minn.	22	44	.1	2,280	6,833.40	88.40	4.02	353.60	16.07	4,140	496.80	2,940	235.20	1,120	56.00	3.80	19.00	807.00	27.25	25.53
Hatton, N. Dak...	23	52	.1	1,310	5,463.20	68.00	2.95	272.00	11.83	3,620	344.40	1,960	156.80	810	40.50	5.20	26.00	657.70	28.06	19.40
Volin, S. Dak.....	24	56	.1	840	4,049.90	51.20	2.13	204.80	8.53	3,730	447.60	960	76.80	1,180	59.00	2.20	11.00	594.40	28.91	16.43
Averages...	.....	.....	.....	.....	.....	.....	3.42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	24.01

[1] In this grove no thinnings had been made, and the plot included an outside row.

The returns from willows planted now may be more fairly estimated on the basis of what the best plantations of the past have done rather than the averages, because the average plantations represent a great amount of poor practice that may now be avoided. The following yields are for groves whose appearance and history show that they have been treated in a rational manner:

TABLE 21.—*Yield of selected willow groves in Iowa.*

Plot No.	Size of plot.	Age.	Yield per acre.	Yield per acre per year.	Location.
	Acres.	*Years.*	*Cords.*	*Cords.*	
1	0.25	11	47.3	4.3	Bottom land.
2	.25	16	76.8	4.8	Do.
3	.25	16	62.4	3.9	Do.
4	.25	18	109.8	6.1	Do.
5	.25	18	81.0	4.5	Do.
6	.25	21	109.2	5.2	Do.
7	.25	21	73.5	3.5	Do.
8[1]	.25	22	116.6	5.3	Do.
9	.25	24	132.0	5.5	Do.
10	.25	25	105.0	4.2	Upland.
11	.25	25	95.0	3.8	Do.
12	.25	31	102.0	3.3	Do.
Average				4.5	

[1] Illinois Agricultural Experiment Station.

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